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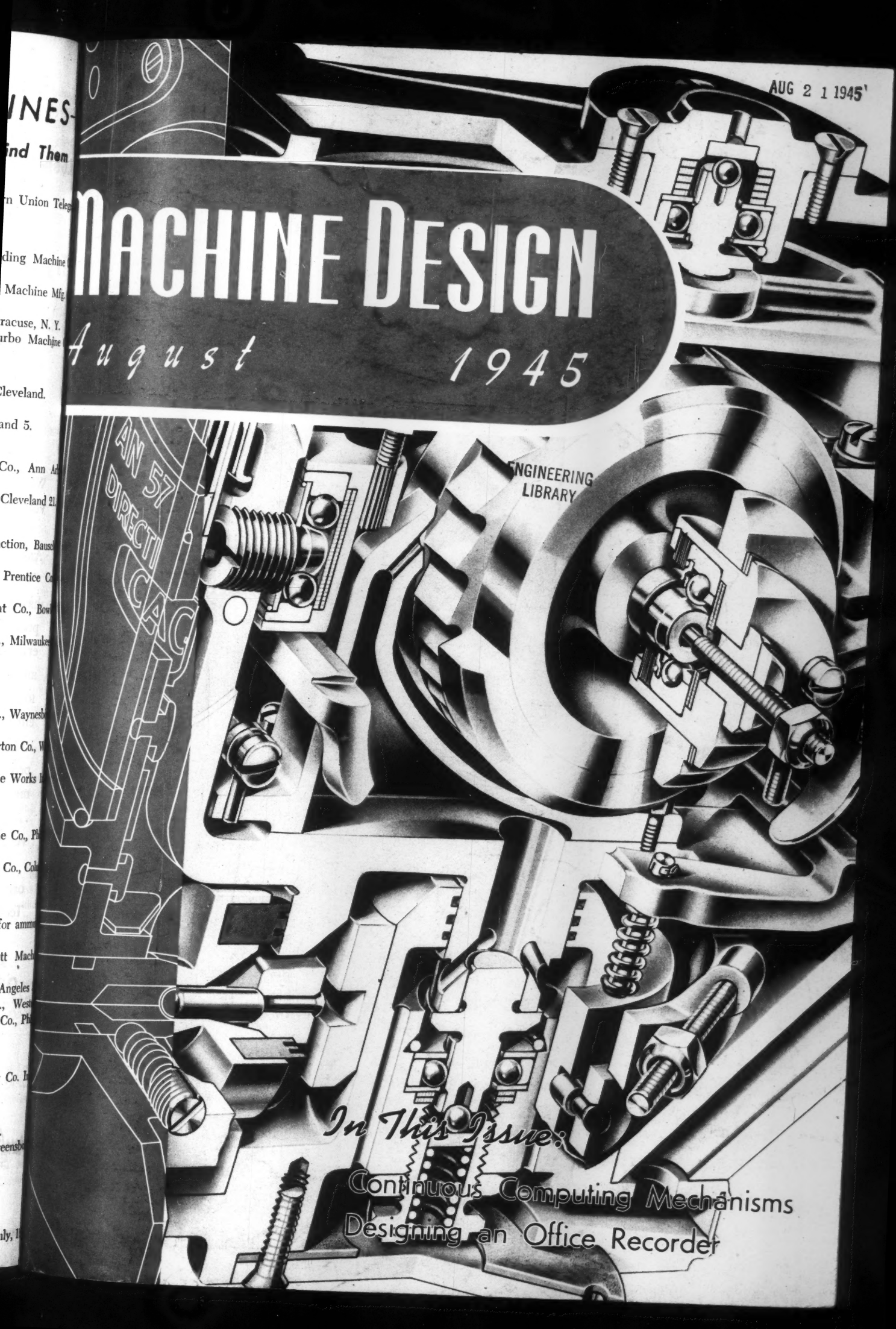
MACHINE DESIGN

August 1945



In This Issue:

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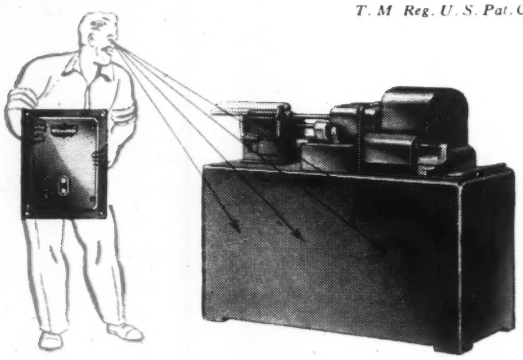

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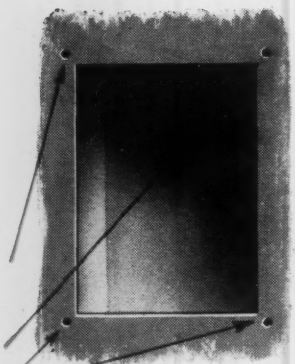

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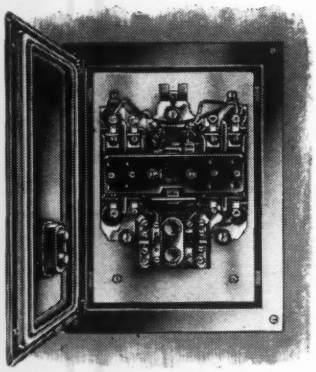

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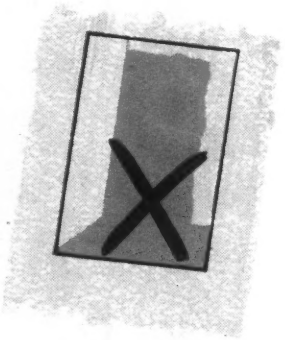

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MACHINE DESIGN

THE PROFESSIONAL JOURNAL OF CHIEF ENGINEERS AND DESIGNERS

AUGUST, 1945 Volume 17—Number 8

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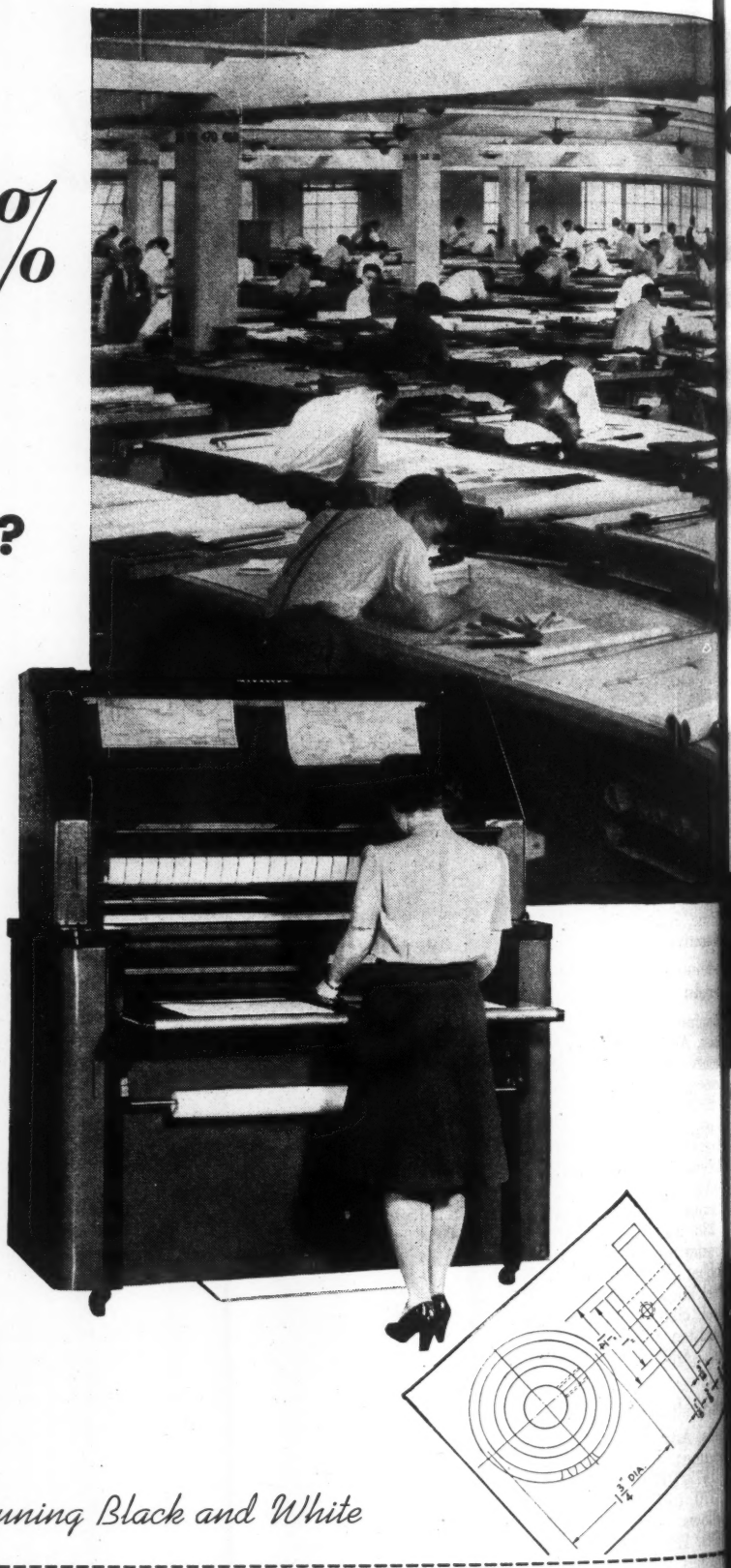

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Topics

CELLOPHANE glued to the inside of glass doors on refrigerators having temperatures as low as –70F prevents frosting of the glass. According to H. J. West of the Penn Electric Switch Co. this method proves helpful and saves much time, particularly if it is required to see inside the compartment.

ERRORPROOF PHOTOGRAPHIC methods measure take-offs and landings of airplanes and have proved to be more accurate, economical and safer than any previous method employed. Motion-picture film exposed double—once to a known grid pattern and once to the moving airplane—make the record, formerly a hazardous task requiring six or more theodolites and operators.

UNSATISFACTORY REPORTS on failure of any part of AAF equipment are sent to Air Service Technical Command for study. During April 30,000 such reports were received and corrective measures devised for return to the field in the form of technical orders.

AMERICAN WAR STANDARD for acme screw threads has been developed with the co-operation of Britain and Canada. It is expected that it will become a national standard in the three countries and that it will fill the needs of a large cross section of industry.

ASPHALT PAINT as a protective coating, being particularly effective against bad weather but weak against the action of hot sun, has been improved so that it now withstands the effect of the latter also. According to the A. C. Horn Co., asphalt containing aluminum is a successful all-weather paint. When applied, the asphalt sinks to the bottom whereas the aluminum floats to the top, reflecting the sun's rays.

CONVEYOR BELT system on Douglas C-47 cargo-carrying aircraft has decreased time required for air crews to drop supplies to ground troops from 40 minutes to a few seconds, according to the Air Technical Service Command. An endless chain driven conveyor driven by a 3.87-hp motor, the belt extends from behind the pilot's compartment to the rear door of the plane, a distance of 22 feet. With this system crew members are exposed to enemy fire for a minimum time.

STRATOCHAMBERS make possible complete tests for Philco military aircraft electronic devices which virtually take them for a flight around the world in 90 minutes. During this simulated flight the weather conditions in every part of the globe may be duplicated at altitudes from sea level to 60,000 feet or higher. Temperatures range from –70F to 158F and relative humidity from less than 10 per cent to practically 100 per cent.

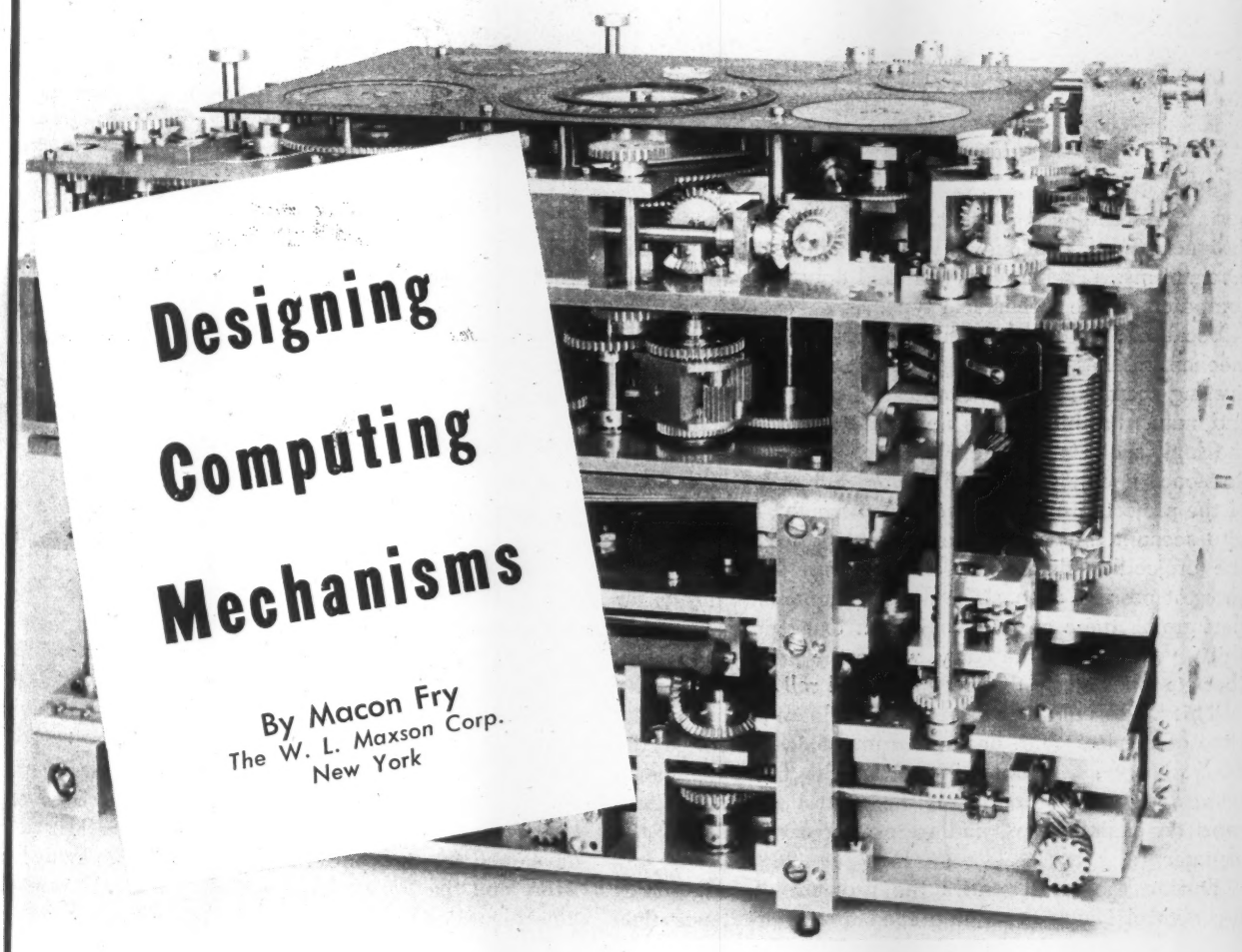
PLASTIC UPHOLSTERY, developed by United States Rubber Co., will provide designers with a material both waterproof and flameproof. Unaffected by perspiration, salt water, alcohol, gasoline, oils, greases, most acids, and alkalis, the upholstery will be particularly useful for open cars, boats and other outdoor installations. It can be cleaned with soap and water and has been adopted by the Navy for equipment on all combat ships.

JET PROPULSION transport for flight not greatly in excess of 500 miles is only slightly higher in cost than that of present-day transport, according to G. E. engineers. For the utmost in speed, disregarding other considerations, jet propulsion is by far the best performer.

DETONATION INDICATOR makes possible 10 to 15 per cent reduction in gasoline consumption in long-haul flight operations. Change in frequency, caused by detonation, is detected by a pick-up unit attached to the engine cylinder wall. This impulse is amplified to flash a neon light on the instrument board.

INDUSTRIAL DESIGNERS have formed a society to establish criteria for ethics, training and practice in the profession. Limited in membership to professional designers, the new Society of Industrial Designers has as officers Walter Dorwin Teague, Raymond Loewy, Henry Dreyfuss, Harold Van Doren and Egmont Arens.

MACHINE DESIGN



Part I—Basic Elements

COMPUTING mechanisms can for convenience be divided into two groups, cyclic and continuous. The cyclic computer, exemplified by the familiar lding-calculator used in every engineering office, per- ms only one operation for a given setup, and deals with tegral numbers. The continuous computer, with which s series of articles is concerned, deals with continually ying inputs which may assume any value, integral or fractional, and yields a continuing solution based upon the instantaneous values of those variables and the relationship connecting them.

Although by far the most intensive development of continuous computing mechanisms has occurred in the field of gun fire-control apparatus, it is believed[1] that the methods employed are by no means limited to this type of equipment. Some extensions have indeed been made, but chiefly in the field of laboratory apparatus. It is in the wide field of industrial and process control that the greatest advances may be expected.

Purpose of this series of articles is to gather together the basic information regarding the design of elements com-

[1] See also "Teaching the Robot to Think Ahead"—Alan Osbourne, *Chemical and Metallurgical Engineering*, April, 1931, Pages 245-247.

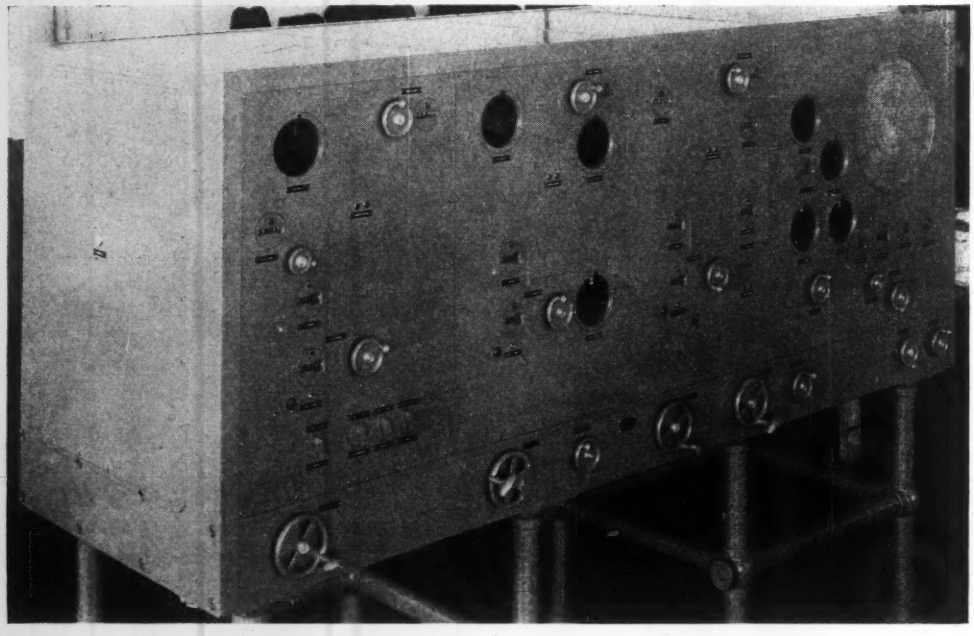
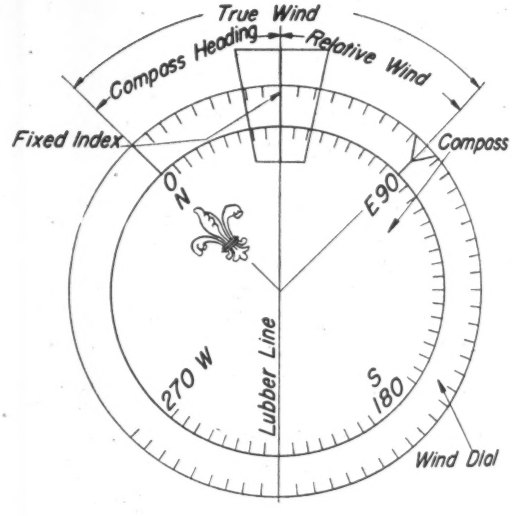


Fig. 1—Left—Gun data c puter, developed for the trol of coastal batteries, recent example of the ap cation of continuous com ing mechanisms. — Ph courtesy U.S. Army

Fig. 2—Below—Example the use of two concen dials which may be r against a fixed index as w as against each othe



posing present-day fire-control equipment, in the hope that designers in other fields will find new applications of these mechanisms. The articles will deal only with continuous computers of the mechanical type.

Because the development of continuous computing mechanisms has been brought about by the need for delivering accurate fire upon targets of ever-increasing speed and maneuverability, it is appropriate to mention briefly the high spots in this development. As is generally understood, not only must all factors influencing the flight of the projectile such as wind, range, height, etc., be taken into account, but also the movement of the target during the projectile's flight; and all this must be done in the shortest possible time. The need for automatic means for performing these calculations began to be pressing nearly thirty years ago in the Navy, where the problem was further complicated by the movement and roll of the vessel.

This need culminated in the development, about the time of the last War, of an instrument designated by the U. S. Navy as a Range Keeper. The first instruments were designed, naturally, for the control of main battery guns on capital ships, and were later extended to other armament.

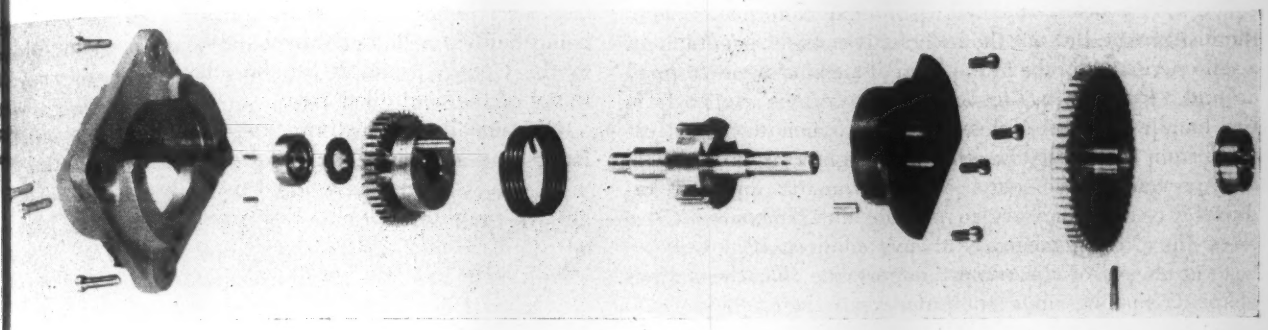
During the mid-twenties the problem of anti-aircraft fire control began to assume even more importance than surface fire control, due to the rapid development of the airplane as an offensive weapon. Here the difficulties were multiplied manifold. The target was much faster and moved in a three-dimensional space. Time for laying the guns had to be reduced and more frequent fire maintained. New instruments were developed following the same principles successfully used in the older surface equipment, with the addition of gyro stabilizers which permitted fire to be continued at any point in the roll. Automatic (synchro) data transmission also became common about this time, both for AA and surface fire control, so that the various elements comprising the system were linked with the guns continuously, requiring no intermediate human agency.

The Army, meanwhile, had not been idle. Similar apparatus, adapted to Army needs, was designed for b anti-aircraft and surface fire control. A recent exam is the Sperry-Maxson Gun Data Computer M1, Fig developed for the control of coastal batteries by the U Army and the W. L. Maxson Corp., and built in prod tion quantities by the Sperry Gyroscope Co.

These methods have been applied also to navigati aids, such as Dead Reckoning Tracers and Line-of-P tion Computers.

In mechanisms of the continuous computing type, mathematical quantities are represented by movements machine elements. These may be translation, as by movement of a push rod or cam follower, or rotation shaft or other part. Transition can be made from representation to another by means of a rack and pin The scale of the movement usually is expressed as many units per inch in the case of translation, or per re lution in the case of rotation.

Choice of the scale is an important consideration. Fr the standpoint of accuracy it is desirable to have the sc as large as possible, that is, to have as few units per i



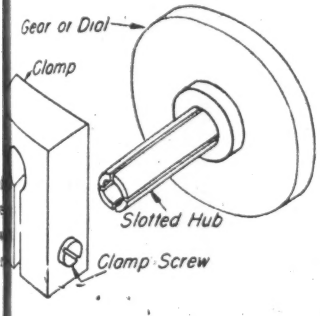


Fig. 3—Exploded view of a line lock mechanism for preventing backout of manually operated cranks

Fig. 4 — Binding clamp suitable for adjustment points

r per revolution) as possible, since backlash and mechanl inaccuracy will then have less effect. A large scale elements operating graduated dials or counters enles readings to be made with greater precision and minizes such factors as twist in shafting. Long shafts should ways have a large scale. On the other hand it usually necessary to keep the instrument within a definite size, hich limits the scales that can be used. Some idea of e proper scales to choose can be judged by the fact that e backlash between a pair of gears cannot be reduced uch below 0.001-inch for interchangeable manufacture. n any particular shaft 0.001-inch at the pitchline of a ar will represent a definite error in the quantity, the agnitude depending upon the scale at that point. Sumng up these errors for the whole train will show whether e scales are adequate.

A quantity need not have the same scale throughout, of urse. It can be stepped up and down at will by suitable ar ratios to fit the scales of various elements it is driving. om the foregoing, however, it can be seen that gear anges should be limited to the minimum possible for curacy.

Concerning accuracy, the U. S. Navy follows a standard actice in designating the various errors in fire control mputing mechanisms which might well be followed by signers of this type of equipment for all uses. Errors e classified *A*, *B* and *C*. Class *A* errors are those due to echanical inaccuracies (backlash, incorrect adjustment, .) and necessarily include reading errors in dials and unters. They may or may not be systematic, depending whether they are due to faulty adjustment or to other uses. These errors, when reduced by correct adjustnt to minimum values possible, represent the *precision* the individual instrument. Class *B* errors are those due mathematical approximations employed in the design. ey are, of course, systematic and identical for all sames of a given design. Class *C* errors are the algebraic ns of the *A* and *B* errors and represent the overall *accuracy* of the individual sample. The limiting values of *A* and *B* errors are specified in the design, and thereby influence the choice of scale and fineness of workmanship, and also the permissible departures from exact analytical methods in the theory of the solution.

Dials and counters are commonly used for indicating the values of input and output quantities, and sometimes for intermediate quantities where needed for calibration. Dials are sometimes compound, reading units and tens. The units dial is then called the fine dial, and the tens dial the coarse. This system can be extended indefinitely—units, tens, hundreds, etc., as in a gas meter. The division between fine and coarse need not be decimal—for example, the fine dial might read inches from 0 to 12, and the coarse read in feet—but ordinarily it is preferable. Various arrangements can be used, such as the fixed dial with a pointer moving around it, or the rotating dial read against a fixed index. Dials driven by different quantities may also be mounted concentrically, and read against each other as well as against a fixed index, thereby yielding additional differential quantities. For example, one dial might represent the compass heading of a ship when read against a fixed index. A second, concentric, dial might represent the wind direction with respect to the ship's course when read against the fixed index, and true wind direction when read on the compass dial, *Fig.* 2.

Counters usually are the familiar Geneva stop type used universally for revolution counting, the last drum generally showing tenths of a revolution, the next whole revolutions, etc.

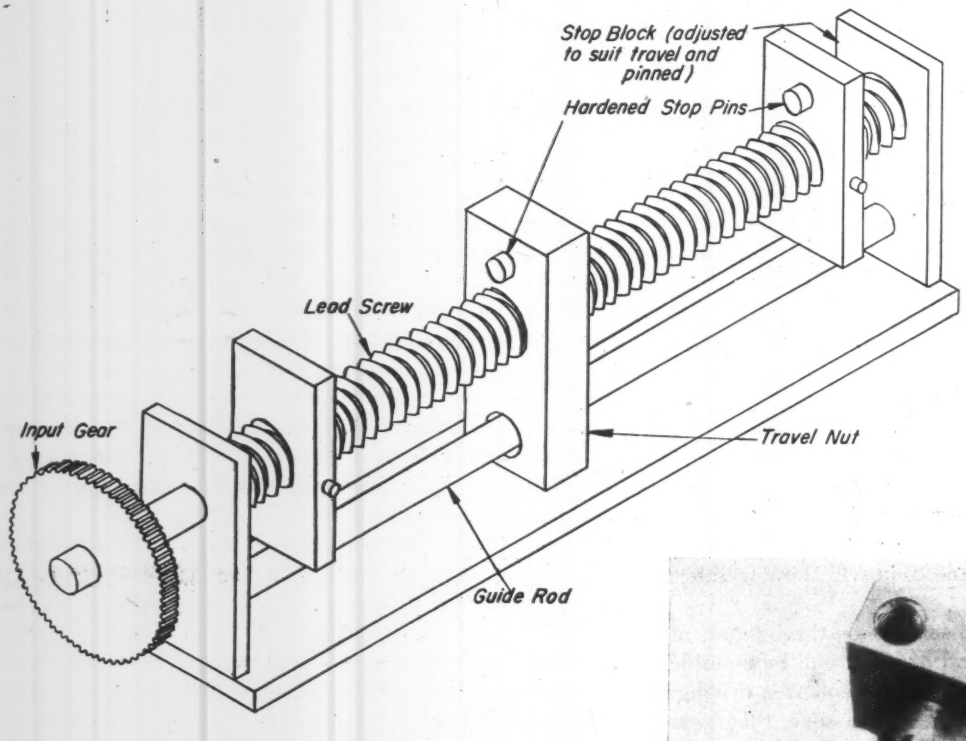
Where quantities can go more positive than negative, it is common to change the reference for numbering dials and counters from the actual zero to some point beyond the most negative number. For example, a certain gun may be able to elevate 5000 minutes above horizontal and depress 1000 minutes below. In this case the most depressed point would be designated zero, horizontal position 1000, and highest elevation 6000. However, if it is decided to use negative numbers, dials must be provided with two sets of numbers running in opposite directions, the negative set preferably red. With counters it is necessary to use two sets, one for positive and one for negative numbers, with a shutter that covers one counter and uncovers the other when the quantity passes through zero.

Input quantities are applied to the mechanism manually through handcranks, or automatically by mechanical or electrical connection with other instruments. Where inputs are applied manually provision must be made to prevent settings from "backing out" after the handle is released. This can be done by frictions on the handles, by irreversible worm drives, or by the use of a mechanism

called a "line lock", which allows motion from the handle to the instrument, but not the reverse. It consists essentially of a self-energizing brake in the form of a coil of wire wrapped around a fixed drum, *Fig.* 3. When torque is applied from the handle the coil is loosened, but when torque is exerted from the mechanism the coil is tightened on the drum and prevents movement. With automatic inputs it ordinarily is not necessary to provide anti-backout devices, since the driving means is always connected.

It is always of the utmost importance that the various elements making up a computer keep their relative calibrations, and to this end the interconnections should be by positive means, such as gearing. Furthermore, gears should be pinned or otherwise firmly secured to their shafts, not by set-screws. However, it is necessary to have means for calibrating the various components after assembly, so a sufficient number of adjustment points must be provided. In some cases this can be done by breaking a gear mesh at a selected point by loosening a bearing bracket, but this allows adjustment only to the nearest tooth, which may not be close enough. In most cases it is necessary to use some form of clamp connection. One method is to have a selected gear equipped with a slotted hub, around which a binding clamp is fitted, *Fig.* 4. Such a device will hold as firmly as a pin, yet will permit easy adjustment. This type of clamp is ideal for securing dials (which may often be made adjustment points). Another type of clamp for connecting abutting shafts is shown in *Fig.* 5.

Since many parts of a mechanism will have a limited range of travel, it is necessary to insert limit stops. These preferably are placed as close as possible to the sources of inertia forces, which usually are on high-speed shafts. Consequently the stop must be capable of making many revolutions. One form of suitable stop is shown in *Fig.* 6.



Genevas* (*Fig.* 7) also are frequently used, the last wh being held to a limited travel. By simply adding whe in the Geneva train, it can be adapted to any range travel of the controlled parts.

Occasionally an instrument will require that one e ment have a definite range of travel, while another e ment driven by the same input quantity may have a mu greater range of travel. For example, in some types

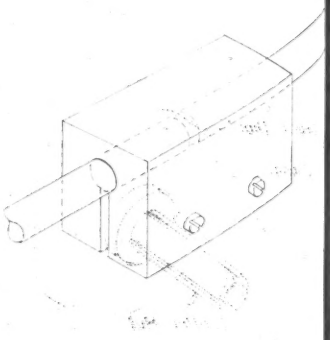
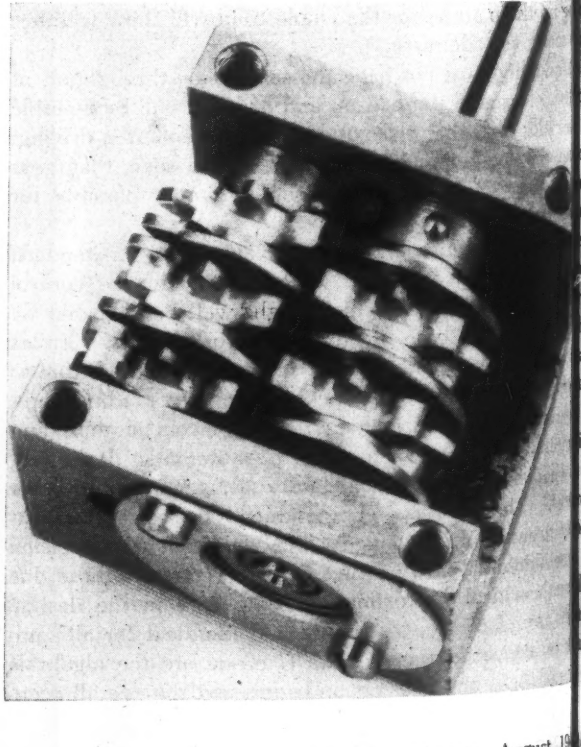


Fig. 5—Right—Another type of adjustable clamp, used for connecting abutting shafts

Fig. 6 — Left — Limit st for permitting a limi range of travel. Should placed as close as pos ble to sources of ine forces

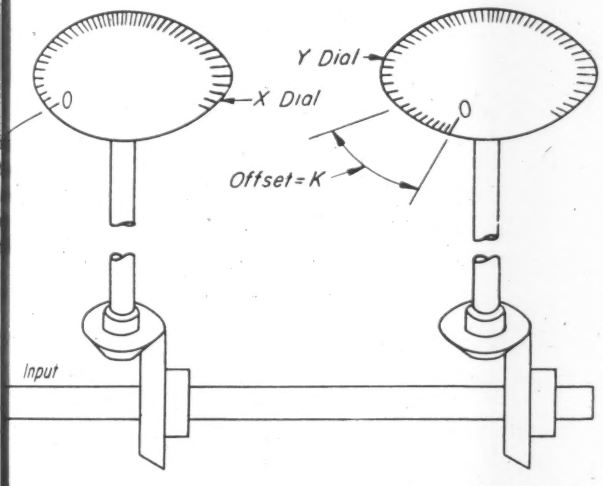
Fig. 7 — Below — Gene mechanisms, often used series to provide a li stop, the last wheel be held to a limited trav



*Genevas and intermittent drives are discussed in detail in most books on Kinematics or Mechanism.

ipboard fire-control equipment it is not considered sible to compute the effect of trunnion tilt beyond 15°; e ship, however, may sometimes roll up to 40°, and the ro will measure and supply this angle to the computer. such cases the part with the limited travel must be otected by an intermittent drive° which disengages and ks the drive to the protected part when the limit is ached, while permitting the input quantity to go beyond e limit. When the input again falls below the limit the rt is re-engaged without loss of synchronism. This device similar to a Geneva, except that instead of having only e tooth per revolution, the driving wheel may have teeth half or three quarters of its periphery, the remainder ing locking space.

Where the input quantity is driven in automatically by servo motor, it usually is necessary to open the circuit



g. 8—Mechanism for the addition of a constant, K, to a variable, x. Y-dial reads the answer

ghtly in advance of the mechanical limit stop. When e limit stop device of *Fig.* 6 is used, this can be simply ne by having the traveling nut strike a spring leaf switch. ch an electrical limit switch must not prevent movement the opposite direction, of course; otherwise the quan- y would get "hung up" on the limit.

Before leaving this preliminary discussion, some men- n should be made of synchro transmission and servo- echanisms. Synchro transmission as such is beyond the pe of this series, a wealth of literature on the subject ing in existence, but due to its close connection with uch fire-control computing equipment, the following ief discussion is included for the sake of completeness. e name synchro is a term covering an electro-mechan- l system whereby the angular position of a shaft is nsmitted electrically over wires to a remote point, where is reproduced synchronously. The shaft at the receiver ll follow every movement of the transmitter shaft with- the torque limitations of the system, and without ap- eciable delay. It behaves as if the shaft at the receiver d were geared to the transmitter. These devices go under variety of names and tradenames, such as telemeter, syn, autosyn, A.C.S., D.C.S., etc. Most of the present y systems operate on single phase alternating current, t there are at least two systems using direct current. excitation from the same source is available at both transmitting and receiving ends, only three wires are required for each circuit; if not, five wires are needed (two to carry the excitation).

There are also differential synchros which permit two electrical inputs from different sources to combine and register the sum or difference of the two inputs.

Positional accuracy of these devices runs between one-half and one degree. Where greater accuracy is required, recourse is had to two-speed transmission, fine and coarse. For example, in transmitting train angles it is customary to make the coarse transmitter 1-speed (360° per revolution) and the fine transmitter 36-speed (10° per revolution). Thus the angular errors of transmission are reduced to 1/36 of their value otherwise, or to about 1 or 2 minutes maximum. Since the torque gradient of synchro devices is extremely small, servo-mechanisms invariably are used in conjunction with them for torque amplification where they supply automatic inputs to computing mechanisms. Sometimes synchro receivers are followed up manually. One method is to use concentric dials; the inner dial is mounted on the receiver shaft, and the outer dial is connected to the manual input drive ("follow-the-pointer"). Another method is to mount the receiver stator in bearings so that it can be driven by the manual input (differential mounting). A single receiver dial is used, and when this dial starts to move off the fixed index in response to a signal, the operator cranks in an equal and

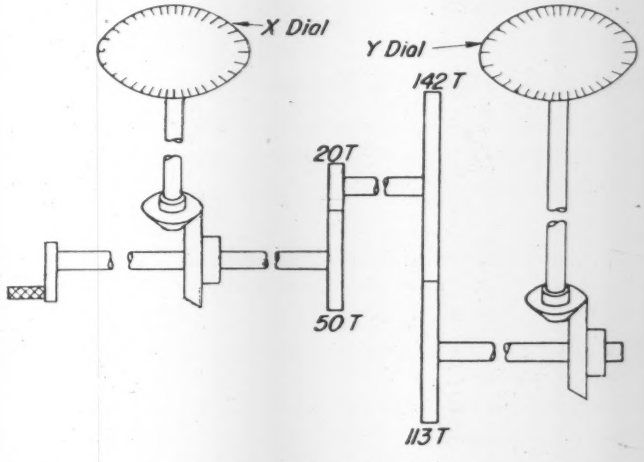


Fig. 9—Illustrating multiplication by a constant

opposite change to keep it lined up ("zero-reader").

A servomechanism is simply a device for mechanically following up the motion of some other element which is not capable of exerting much force, or whose accuracy would be impaired by the imposition of force. They are used widely in computing mechanisms and take a variety of forms, including electrical, hydraulic, pneumatic, magnetic clutch, and mechanical clutch. Some types involve the use of vacuum tubes or thyratrons. Some, such as the Waterbury speed gear (hydraulic) are able to move the turrets of battleships. In computing mechanisms, however, most servos are required to produce only a moderate torque amplification and usually are electric motors of the two-wire reversible type, which are capable of being reversed by a one-pole, double-throw switch. Devices are added to reduce hunting and overrun, and increase dy-

namic accuracy. A thorough mathematical treatment of servos is contained in Dr. Hazen's classic work[2]. Servomechanisms will be treated in more detail later in this series where they occur in connection with other mechanisms.

With the foregoing background of basic concepts and elements, the mechanisms for performing various mathematical processes will now be discussed in detail.

ADDITION OF A CONSTANT: The simplest mathematical process is the addition of a constant to a variable:

$$y = x + K$$

In any computer such a constant as K is added simply as

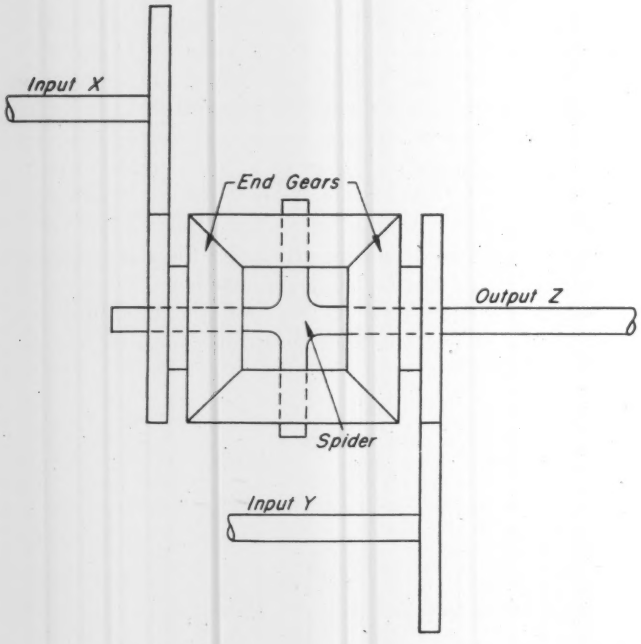


Fig. 10—Differential gear for performing addition or subtraction of two variables

an offset to a dial or other part so that y is always K greater than x, *Fig.* 8.

MULTIPLICATION BY A CONSTANT: To multiply a quantity by a constant,

$$y = Kx$$

a gear ratio equal to the constant must be interposed, if the scale is to be the same for both y and x. For example, suppose a mechanism is desired that will calculate the circumference of a circle when the diameter is given, or:

$$y = \pi x$$

where x is diameter and y is circumference. The ratio 355/113 expresses π to seven significant figures. However, a 355-tooth gear is undesirably large, so it would be preferable to break this up into a compound change of say, (50/20) × (142/113), as shown in *Fig.* 9.

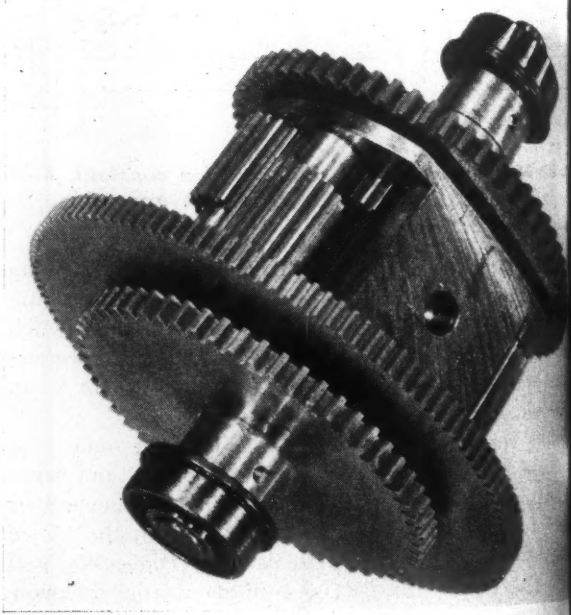
Sometimes the multiplication can be accomplished simply by a change of scale, especially when the quantity concerned drives a dial. In the foregoing example, if the graduations on the x dial had π times the spacing of those on the y dial, no gear change would be needed.

ADDITION AND SUBTRACTION OF TWO VARIABLES: The general formula for addition and subtraction is

$$z = x \pm y$$

This operation is performed by a differential gear, identical with that found in automobile rear ends, *Fig.* 10. It should be noted that there is always a change in scale going through a differential. If the two input variables enter on the end gears, the spider, representing the sum or difference, has twice the value per revolution of either of the inputs. This can be realized by holding one input, say y, stationary and revolving x. The spider will move only half as much as the x end gear, yet this motion will represent x; therefore the scale value per revolution is double. Whether a differential adds or subtracts depends upon the sense of the inputs. If both end gears turn in the same direction for increasing values of input, then the differential adds; if reverse, they subtract. The sense can, of course, be changed simply by inserting an idler in one input. It should be noted that the end gears need not necessarily be the inputs and the spider the output. The

Fig. 11—Spur gear differential, which does same job as bevel gear differential shown in Fig. 10



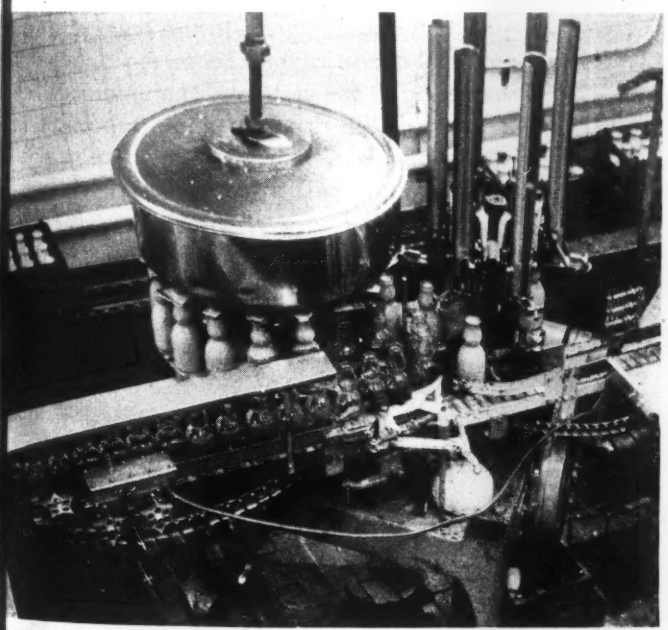
spider can be one input, if desired, and one of the end gears the output. It must be remembered, however, that the scale value per revolution of the spider is always twice that of either end gear, regardless of whether it is input or output. Although *Fig.* 10 shows a bevel gear differential for clarity, spur gear differentials also are often used, *Fig.* 11.

In the second article of this series, to be published next month, the design of mechanisms for performing multiplication and division of variables will be discussed. In addition the methods used in computing trigonometric functions will be considered.

[2]H. L. Hazen—"Theory of Servo-Mechanisms", *Journal of the Franklin Institute*, Vol. 218, No. 3, Pages 279-331; and "Design and Test of a High-Performance Servo-Mechanism", *ibid*, Vol. 218, No. 5, Pages 543-580.

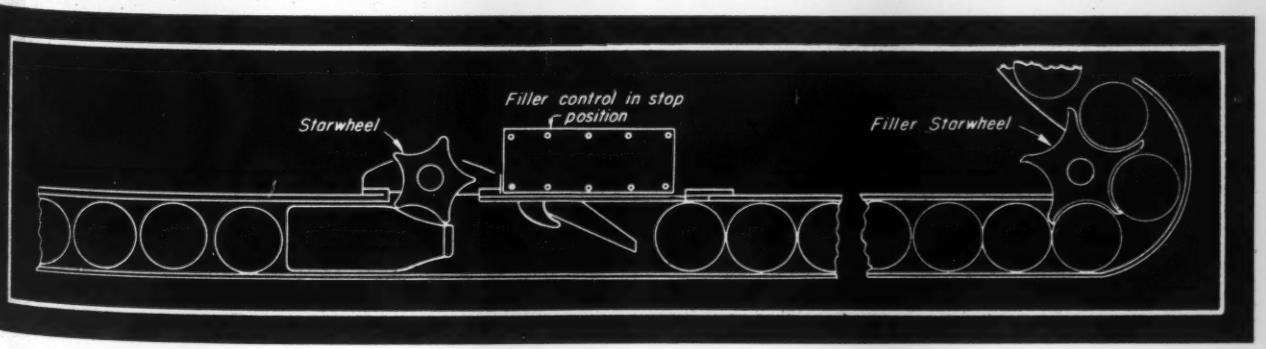
Scanning THE FIELD for Ideas

Automatic control for bottle filling equipment shown installed in a dairy, below, and schematically at the bottom of page allows the filler to run at maximum speed and with minimum attention by assuring that bottles are in filling position while the filler is running. If not, the filler will stop until a sufficient number of bottles is in position. Then it will restart automatically. Designed by C. N. Bergmann, Pittsburgh, the control employs a starwheel, two pressure control arms and switch mechanism located on the feed conveyor.



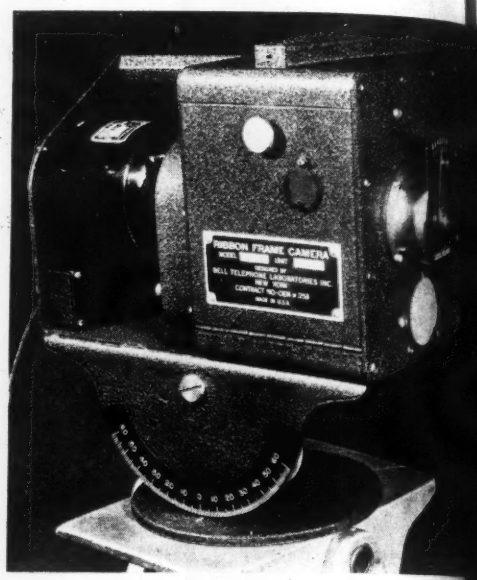
In the sketch an upset bottle is stopped by the starwheel. The control arm therefore opens the circuit of the filler because of the discontinuity in the feed conveyor as shown. Operation resumes when the fault is corrected and bottles refill the conveyor. Likewise, if the bottle supply does not keep up with the filler, it is stopped until the supply is resumed, allowing the filler to be set at maximum speed without endangering its operation. When the supply to the attachment falls below the speed of the filler and the bottles become separated a distance of six inches, the control arms of the attachment will open and stop the filler even though the space between the attachment and starwheel entrance to the filler is full of bottles. This prevents jamming and possible breakage which may result if bottles are not close together at the filler. In this way the control will maintain continuous operation when the bottle supply is adequate.

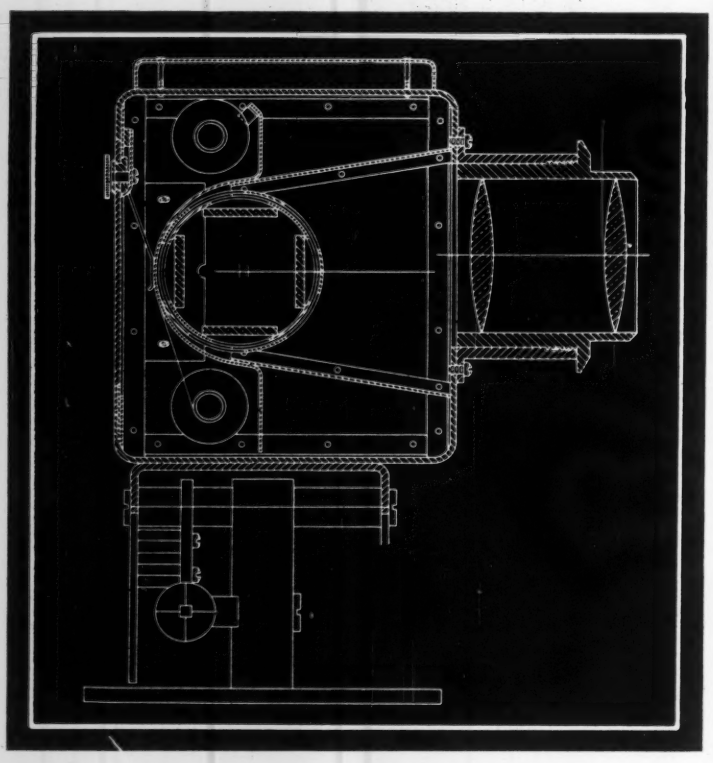
Ribbon-Frame camera is capable of exposures between 0.0001 and 0.0006-second, producing over 2000 frames on a standard No. 122 film which is 3¼-in. wide and 35-in. long. The film is carried past a 0.15-



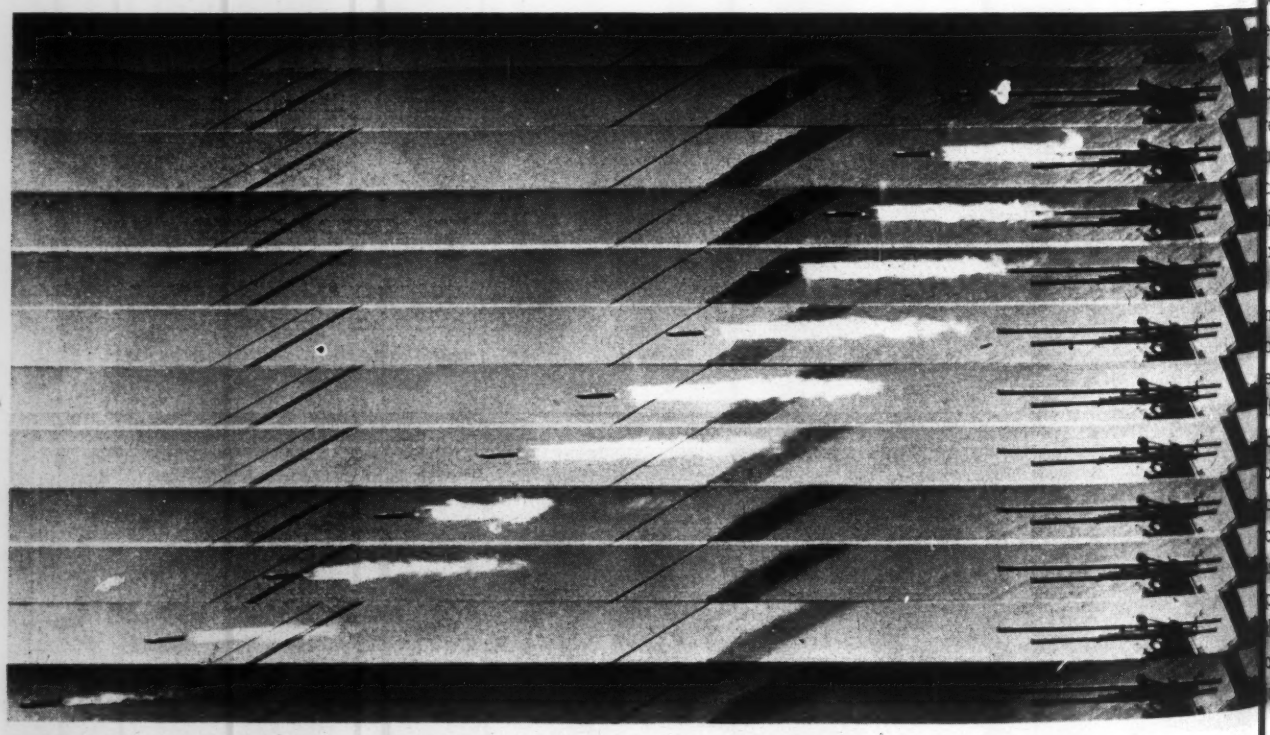
in. slit, each frame thus being 0.15-in. by 3¼-in. which accounts for the camera's name. Developed by the Bell Laboratories to gain knowledge of the behavior of rockets during the early part of their flight as shown in the series of pictures below of a 4½-in. rocket, the camera (at right) is ingenious in design and applicable to the studies involving relatively straight-line motion.

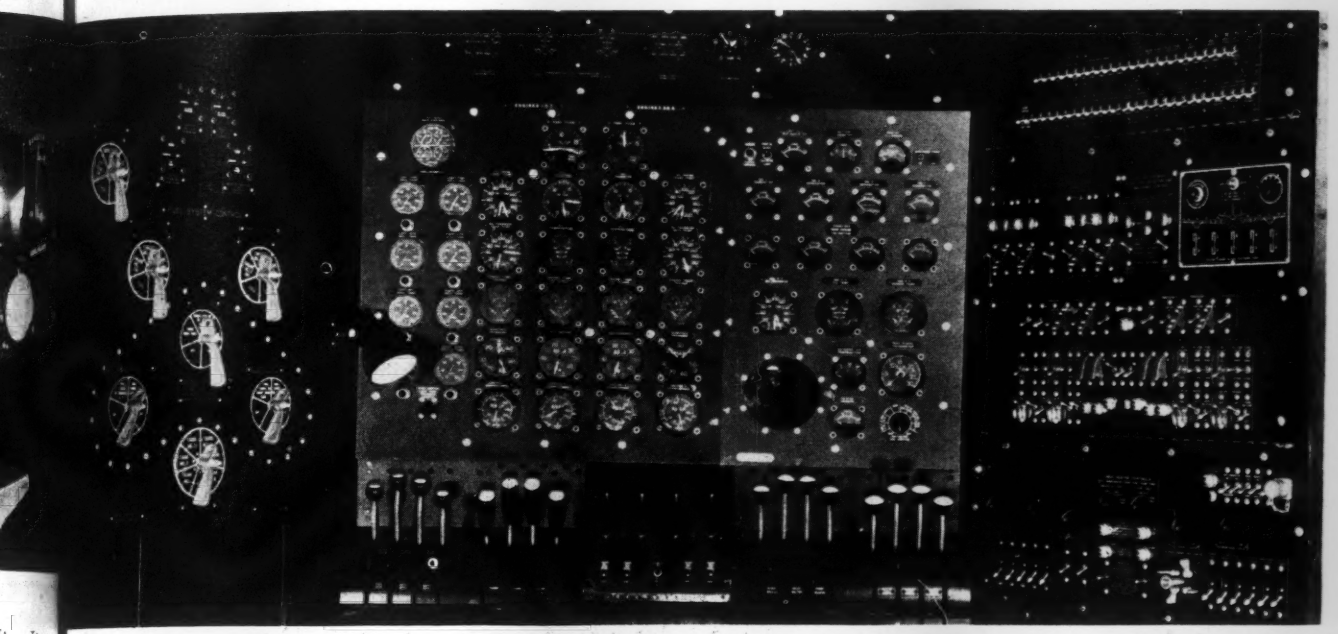
One of the novel features is the shutter arrangement





shown in the sectional view at left. It co
sists of two concentric drums which are r
tated in the same directions but at slight
different speeds by a single constant-spe
motor. In each drum there are wide slo
four in the inner and five in the outer. A
slots in both drums are 40 degrees wide, b
the solid sectors are 50 degrees in the inn
and 32 degrees wide in the outer drum. B
cause of the difference in the number a
spacing of the slots and the difference in t
speed of the drums a wide gap at the le
side and a narrow gap at the film side
the shutter will appear after each quar





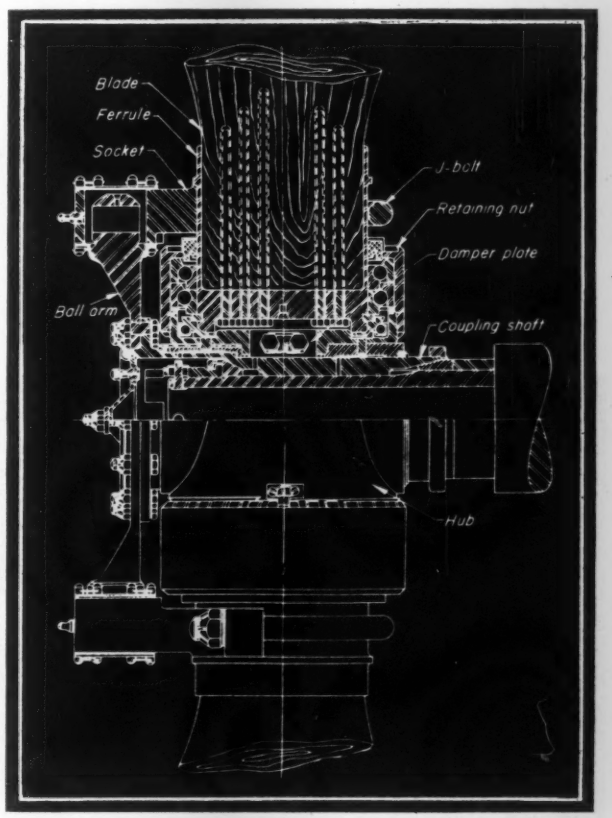
urn of the inner drum. Thus the shutter is opened and closed four imes for each revolution of the inner drum. The 0.15-in. slit is mounted n a light shield between the outer drum and film.

The film has a continuous speed and moves from 0.002 to 0.010- n. during the short exposure time. To prevent blurring the image, our optically flat glass plates are attached to the inner drum as hown. Thickness of the plates is chosen so that the refraction of the ight rays downward as the drum rotates approximates the film mo- ion during the exposure.

Subassembly construction for the flight engineer's panel above on the 85-ton JRM Mars airplane allows workers to perform four times as much work per man with less effort than when the panels were assembled in the

Constant speed at rated maximum engine out- ut is maintained by the automatic propeller itch control shown at right. Developed by Wick- wire Spencer Aviation Corp., no auxiliary power quipment or manual controls are involved in this ompensated design. Adjustments are provided to alance the speed against the engine torque. This elationship remains constant thereafter throughout ll conditions of airplane flight, the engine torque cting to decrease the pitch and the centrifugal ac- ion of the blade tending to increase the pitch with ncrease in speed.

As torque and speed are independent of aerody- namic considerations this control is independent of irspeed and air density. Changes in engine pow- r developed, however, will reflect in speed change. f the engine is throttled the speed will be reduced ecause the horsepower is proportional to the cube f the speed. Likewise, if the power is decreased y virtue of reduced air density the speed will de- rease. Referring to the sectional drawing, drive through the ball arm and its socket to the pro- eller. Torque of the socket arms acts to decrease e pitch. Simplicity of this design, and its depend- bility on only torque and speed for automatic ad- ustment provides a lightweight pitch control.

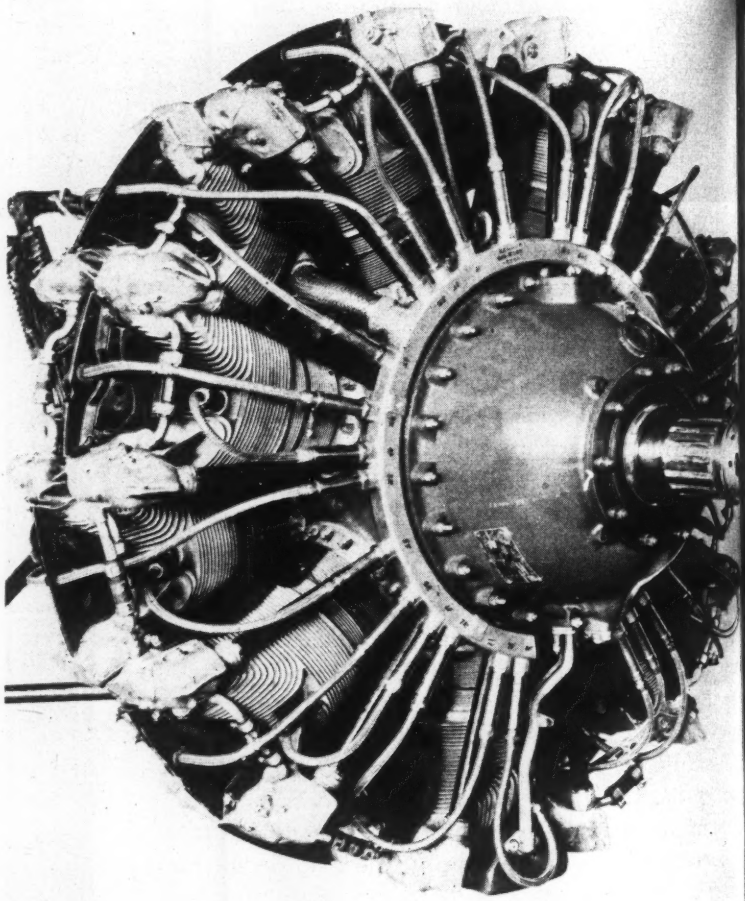


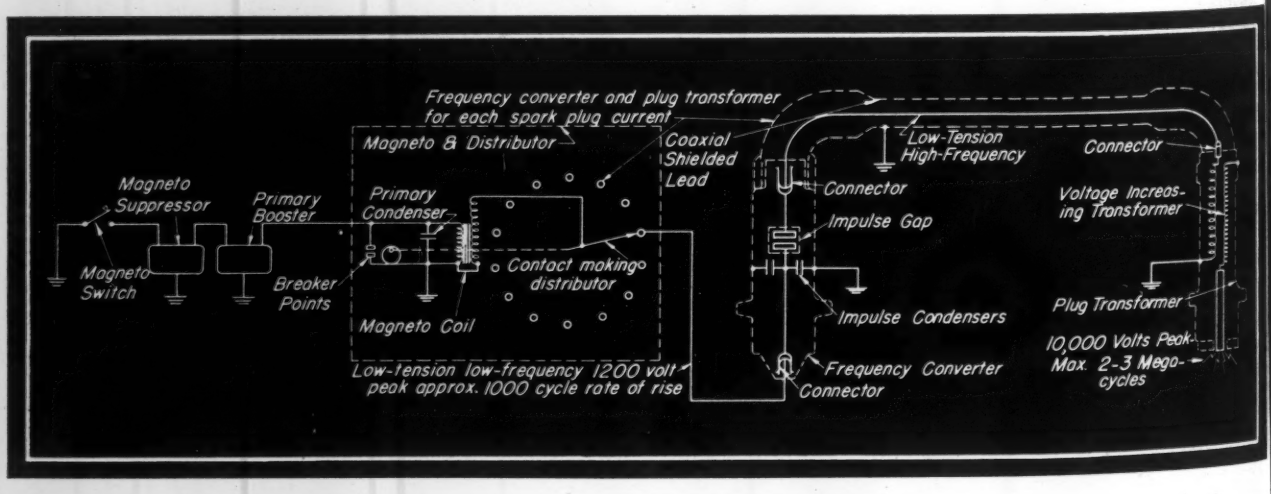
ship. By applying techniques of familiar mass production methods, designers and engineers of the Glenn L. Martin Co. evolved this easy and improved method of assembling. The instrument panel is composed of a center and two side-wing sections, with the fuel system controls and water separators at the left, the operational master-switch panel at the right, and the center section containing 31 gages and meters. When installed in the ship, two thousand two hundred wires of various sizes are connected to terminals at the back of the panel. These wires, which total a distance of more than two and one-half miles, are coded by number to match the terminal numbers on the panel, providing ease and accuracy in connecting.

High-frequency ignition system for aircraft engines reduces the menace of fouled spark plugs and insures engine performance at extremely high altitudes. Also the system provides greater engine output, increased spark plug life, reduction in radio interference and savings in weight. Developed by P. R. Mallory Co. Inc. with the support of the Army Air Force, Air Service Technical Command and engine manufacturers, the system is shown schematically below and installed on a Pratt & Whitney engine at right.

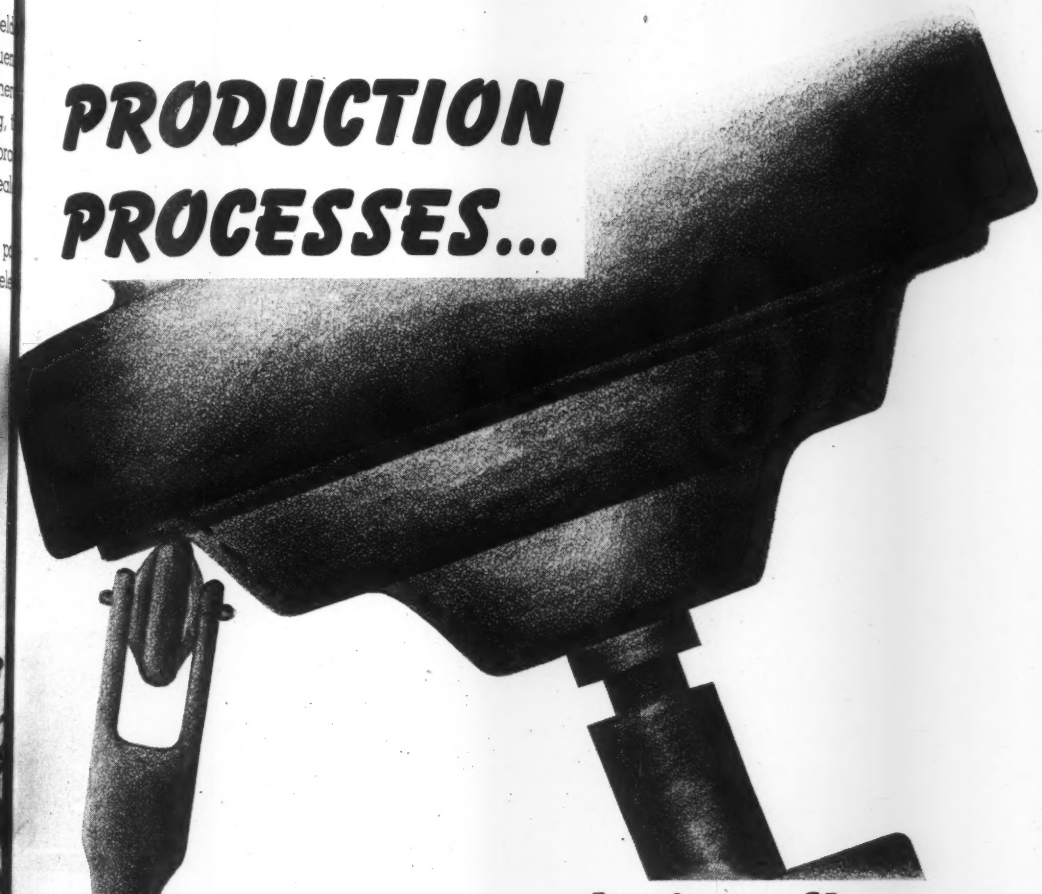
In this new distribution system, low voltage of approximately 1200 volts is generated in a magneto and distributed through shield leads to the spark plug. At the manifold ring the low-freque energy of the magneto is converted to radio-frequency ener by an impulse type frequency converter. At the spark plug, t low-tension high-frequency energy is stepped up to appro mately 10,000 volts by a small transformer hermetically seal in the well of a standard aircraft spark plug.

Weight reduction of 10 pounds or more per engine is po sible over conventional ignition because of the low level of el trical energy required of the magneto.





PRODUCTION PROCESSES...



Their Influence On Design

By Roger W. Bolz
Assistant Editor, Machine Design

Part II—Spinning

MANUAL metal spinning, though firmly entrenched as a valuable small-volume production process, is in a large measure the work of a skilled craftsman rather than the mechanical output of a highly automatic production machine. Somewhat less versatile but well adapted to a great many unusual forming jobs, automatic mechanical metal spinning rounds out the process possibilities to include large-volume applications. An almost unlimited variety of circular shapes can be produced by manual spinning on solid or collapsible forms of wood or steel and even "on air." Where nonstandard shapes subject to continuous change, parts for research projects or components for experimental machines are required, manufacture by manual metal spinning —wholly or in part—is often the most economical and many times the most satisfactory. This is especially true in cases where odd conical parts, exact parabolic contours, extremely large diameters, and special types of material are specified.

Repetitive production of machine parts by manual spinning is a quick and, as a rule, an inexpensive operation for not only are the necessary forming tools of simple construction, but the usual hard wood forms are low in cost and readily reworked or otherwise

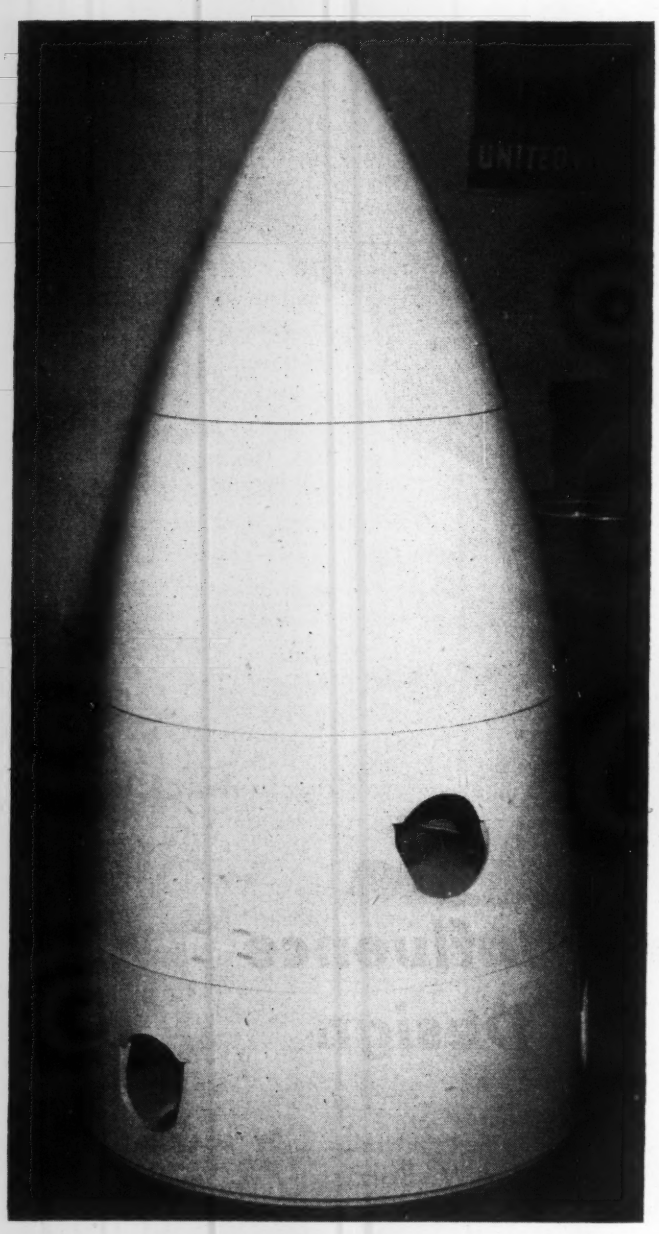


Fig. 1—Above—Spun metal tail section of an airplane 72 in. long and 40 in. in diameter. To accommodate the internal mechanisms the unit is made in four parts

changed to suit new developments in design. The advantages of manual spinning, therefore, lie in the speed and economy of manufacturing small-volume and special parts, *Fig.* 1, where tool and die costs for other forming methods are prohibitive. Cost comparisons show that production quantities are normally limited to 1000 pieces or less, especially for parts where design changes are not contemplated. If a 5000 to 10,000 piece order is to be filled, frequently the cheapest and most satisfactory process would be mechanical spinning, stamping or drawing. However, a great many composite parts such as the machine pulley shown in *Fig.* 2, because of the quantity, size or design, lend themselves best to production by spinning. Large-volume manufacture of these and similar parts is usually by means of automatic mechanical spinning rather than the manual method. Thus, the process, manual or mechanical, finds ready application in many phases of production.

Spinning of oval or elliptical parts is possible on s
cial machines designed for oval work, but such parts
general production are often impractical or too expens
For economical and efficient adaptation to the process
is readily apparent, therefore, that the general form
parts contemplated should be round, concentric, cy
drical, hemispherical, conical, or a part or segment of s
shapes. Sizes of parts which can be handled on ordin
spinning lathes available today range from ¼-in. to so
where around 120-in. in diameter. Practically any k
of sheet metal that can be formed or deep drawn can
spun. The most common of these are commercially p
aluminum, pewter, steel, copper, brass, tin, zinc, and nic
silver. In most cases, at least at present, spinning of
softer metals is limited to gages up to ¼-in., low-carb
steels up to 3/16-in., cold-rolled steels up to 5/32-
stainless steels up to ⅛-in., and nickel alloys up to 5/64-

Any of these metals that can be spun can also be sp
after perforating. Even expanded metals can be hand
with good results when required. Spinnings have be

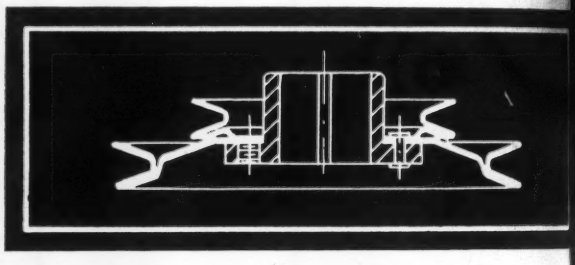
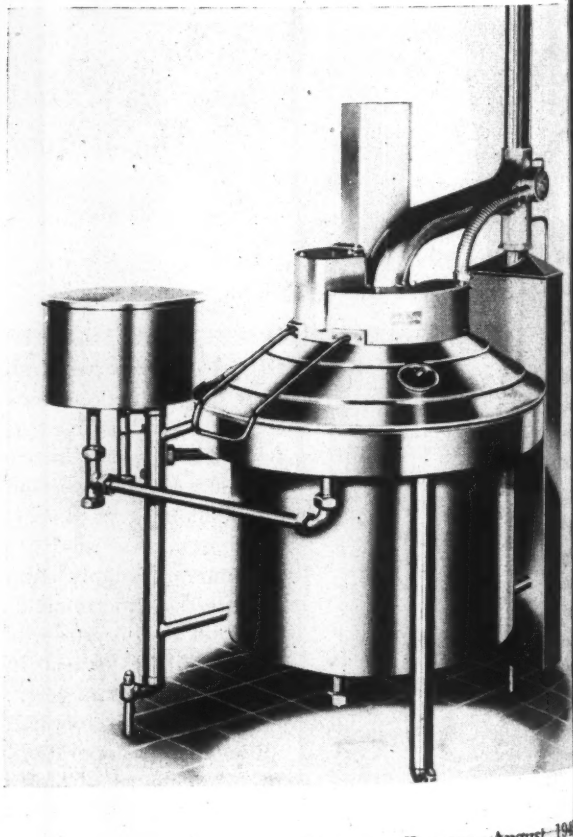
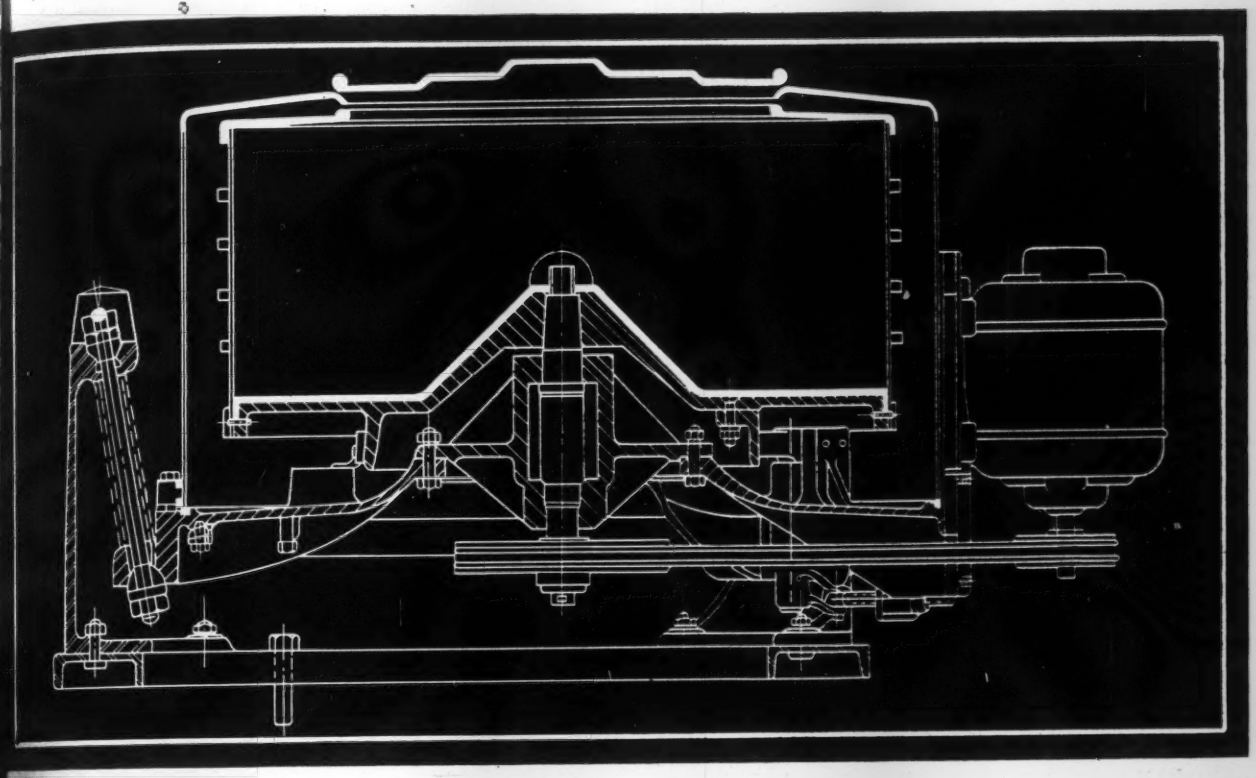


*Fig. 2—Above—Machine pulley mechanically spun fr
steel on a special automatic machine*

*Fig. 3—Below—Stepped cover, tank, tank cover, and li
of this milk irradiator are spun from stainless steel*





g. 4—Above—Commercial centrifugal laundry dryers utilize many parts produced by manual spinning

ed in fabricating odd-shaped covers, venturi tubes, nsmission housings and crankcases both in steel and uminum by cutting and welding together segments of innings or by welding spun sections to stampings, cast-gs, shapes, etc. Spun tanks, floats, shields, dust covers, ys, etc., of aluminum or stainless steel are used widely food machinery, bottle filling equipment, automatic ilk processors and irradiators, *Fig.* 3, and commercial undry equipment, *Fig.* 4. Aluminum tubes may be flared, nged, have the ends rounded or closed and sealed or pered for a great variety of parts required in aircraft nstruction.

Unusual Shapes Practical

Intricate shapes or parts which cannot be spun manually on an ordinary open chuck (spinning block) often n be produced on a two-piece, on a sectional or on an f-center roll chuck, *Fig.* 5. Work such as that shown in g. 5 is first either spun or drawn to a plain cylindrical ape or cup and then mounted for the final inside spinng, bulging or necking operations. This procedure proides a practical method for obtaining unusual shapes mbining expanded and reduced circular sections.

Design: Many of the important factors incident to good inning design closely parallel those for stampings or ep-drawn parts. These important points include maial thickness, bend radii, depth of spinning, diameter d steps in diameter, and workability of the material. onical shapes and variations illustrated in *Fig.* 6 are obably the forms reproduced most easily on the metal inning lathe. Hemispherical shapes illustrated in *Fig.* are somewhat more difficult to produce, especially in fullpth parts. Cylindrical or cup-shaped pieces, *Fig.* 8 are

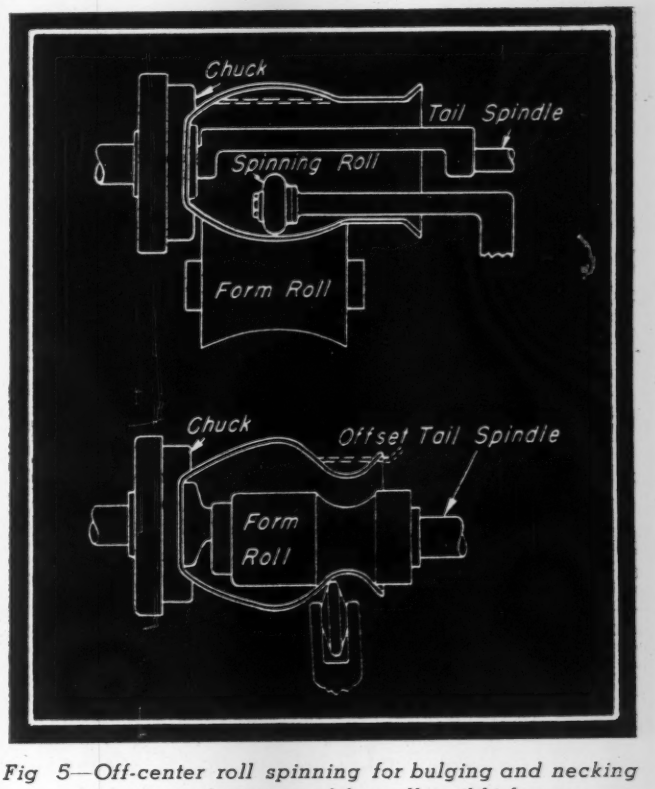


Fig 5—Off-center roll spinning for bulging and necking operations obviate need for collapsible forms

the most difficult of the simple shapes. Plain cylinders can be produced in small lots if sufficient wall thickness is allowable to provide enough metal to work. Diameter and length of cylinders must be balanced with the metal gage to assure minimum wall thickness variation. Oval parts can be spun with a difference between the major and minor diameters of 10 in., maximum. The major diameter of

simple elliptical shapes is limited to about 70 in. on shallow work and 54 in. on deep work.

With deep-spun parts requiring a great deal of working, metal strain or cold working is the greatest and depending on the properties of the material, spinning to full depth requires a number of partial breakdowns with accompanying intermediate annealings. *Fig.* 9 shows such a breakdown sequence for a dished head spun from heavy steel. In a plain deep drawing steel, a head of this type can be spun economically from No. 10 U. S. gage stock

TABLE I*

Spinability Ratings in Various Groups of Metals

Type	Shallow Work	Deep Work
Group A—Aluminum Alloys		
2S-0	1.00	1.00
3S-0	1.00	.995
17S-0	.65	.45
24S-0	.65	.45
52S-0	.98	.62
53S-0	.98	.62
Group B—Copper and Copper Alloys		
Admiralty Brass	.82	.70
Cartridge Brass	.99	.91
Commercial Bronze (Gilding Metal)	1.00	1.00
Copper (Cold rolled annealed)	1.00	1.00
Copper (Hot rolled)	.99	.88
Eyelet Brass	.99	.91
High Brass (Yellow spinning)	.99	.99
Low Brass	.99	.88
Muntz Metal	.55	.15
Naval Brass	.75	.25
Nickel Silver (Up to 30 per cent	.98	.87
Phosphor Bronze (5 per cent-soft)	.85	.45
Red Brass	.98	.89
Silicon Bronze (ASTM B97-41 type A)	.965	.85
Silicon Bronze (ASTM B97-41 type B)	.97	.87
Group C—Steels		
Cold Rolled Deep Drawing	1.00	1.00
Enameling (Extra deep drawing)	1.00	.94
Annealed Zinc Coated Low Carbon	1.00	impractical
Galvanized Sheet	.91	impractical
Hot Rolled Pickled Drawing	1.00	.80
Hot Rolled Copper Bearing	.88	.51
Hot Rolled Dead Soft	.88	.51
Lead Coated (Long Ternes)	1.00	impractical
Manganese Silicon High Tensile	.45	.15
High Carbon (40 per cent and up)	.25	.10
Group D—Stainless Steels		
AISI-302	.98	.50
AISI-304	.98	.98
AISI-316	.98	.50
AISI-347	1.00	1.00
AISI-430	1.00	.80
Group E—Nickel and Nickel Alloys		
Inconel	.95	.88
Monel (Cold rolled deep drawing)	1.00	.96
Monel (Standard cold rolled)	.95	.80
Nickel	1.00	1.00
Group F—Miscellaneous Metals		
Lead	.96	.90
Pewter	1.00	.99
Zinc	1.00	1.00

*The unit 1.00 is given the material in each group which lends itself most readily to forming by the cold metal spinning process. Ratings are indicative only. Courtesy Milwaukee Metal Spinning Co.

in diameters ranging anywhere from 15 in. up to about 84 in. On the other hand, it is impractical to attempt the same shape from this gage material, say in a 2 in. or 3 in. diameter. A lighter gage of the same stock—No. 16 U. S. gage—would be a practical limit.

The area of blank stock for a spun part should as a rule be approximately equal to the surface area of the finished part. Normally the stock decreases somewhat in gage or thins out during the processing and naturally increases the stock area. This increase in area will usually provide sufficient metal for trimming, flanging, rolling or wire beading.

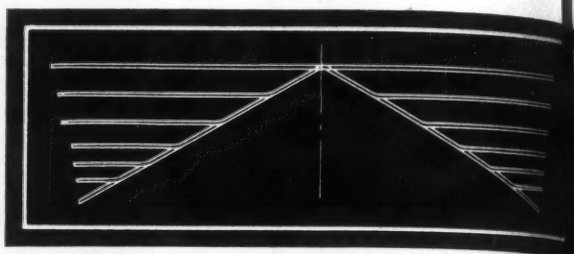
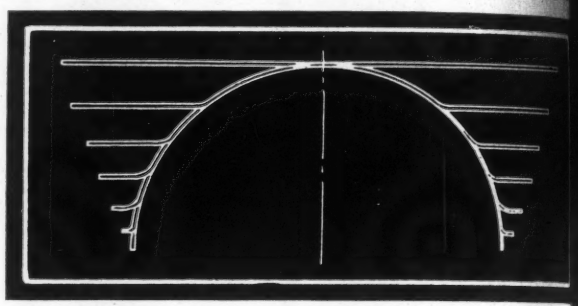


Fig. 6—Above—Conical shapes are simplest to reproduce

Fig. 7—Below—Hemispherical shapes present no problem until full depth parts are required to close tolerances



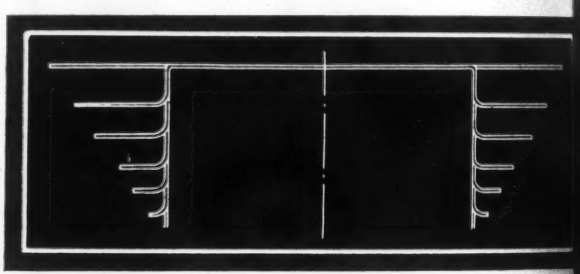
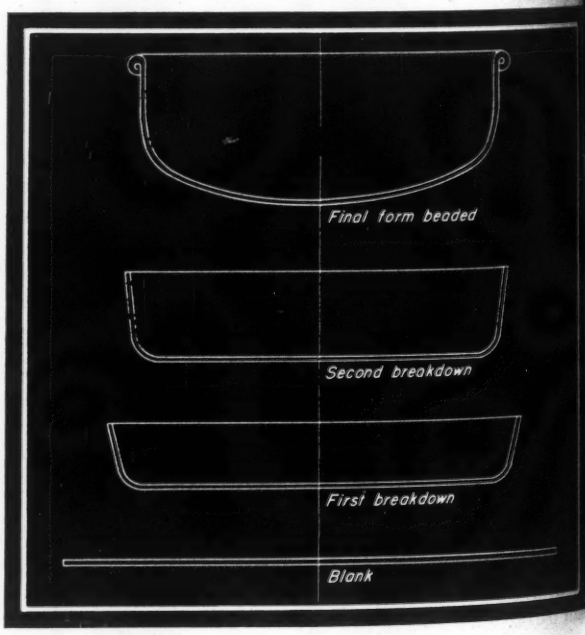
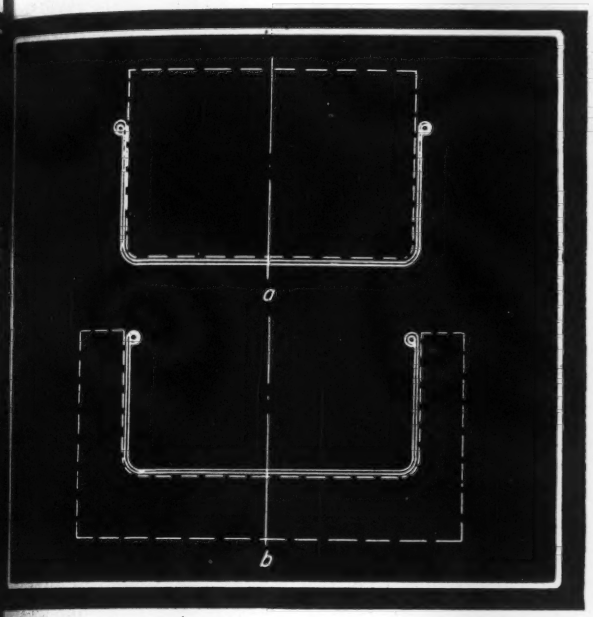


Fig. 8—Above—Most difficult to reproduce of the simple shapes are cylinders or cup-shaped parts

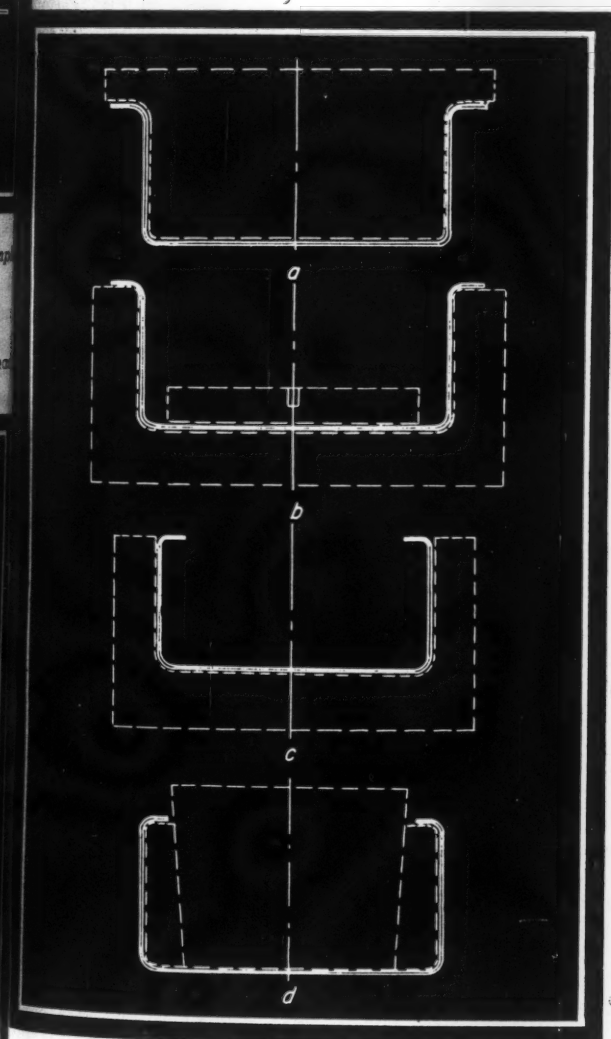
Fig. 9—Below—Breakdown sequence for a dished head spun from deep drawing steel sheet





g. 10—Above—Outside bead shown at a should be used ere possible to eliminate special form for inside bead

g. 11—Below—Simplest form of plain flange shown at a, ecial squaring form b, plain inside flange at c, and form for exacting inside flange at d



Where parts require a strengthening bead or wired roll over the edge, the most economical form is the outside bead as shown in *Fig.* 10*a*. The inside bead, as in *Fig.* 10*b*, entails a greater cost since it involves the use of an extra form and a special setup. Similarly, the outside flange, shown in *Fig.* 11*a*, is the simplest type to reproduce. If the flange angle can vary from an exact 90° by plus or minus 1/16-in. at the outer edge, a special or squaring form, *Fig.* 11*b*, to remove the metal springback is not necessary. Where an inside flange is required, *Fig.* 11*c*, tooling requirements are about the same as that for the perfectly squared outside flange, assuming liberal depth and diameter tolerances. However, if such an internal flange must be exact in diameter and depth, a more complicated sectional form, *Fig.* 11*d*, must be utilized.

Streamlined Curves Advantageous

Streamlined or smooth curves and large radii are an aid both to manufacture and improved appearance. Stepped sections can be much more easily produced if conical steps with large radii are specified, *Fig.* 12. Inside form radii of ⅛-in. minimum can be held with practically any metal. More generous radii, however, simplify the production problems, especially with metals which work-harden rapidly. In hot-working magnesium, the minimum inside radius possible without cracking is usually limited to about twice the sheet thickness. However, specifying maximum allowable radii wherever possible simplifies production considerably.

MATERIALS: Besides the common softer metals which are easy to spin, less ductile materials such as stainless steels, aluminum alloys, bronzes, nickel, Monel, Inconel, steel alloys, and high carbon steels can be successfully handled by gradual breakdowns and intermediate annealings. Number of breakdowns, *Fig.* 8, is entirely dependent upon the rapidity with which a particular material work-hardens in processing. Magnesium, unlike the other less ductile materials, can only be spun in small amounts and extremely shallow shapes while cold. However, spinning is successfully accomplished by working the material at a temperature of 450 to 600 F. Wooden forms or chucks are satisfactory for a few pieces, but if larger quantities are required, the cost per piece increases because metal chucks (usually cast aluminum or magnesium) are necessary to withstand the heat. Magnesium sheet .032-in. thick by 36 in. in diameter has been hot-spun into parabolic propeller spinner cowls 16 in. in depth by 24 in. in diameter at the base, indicating the wide range of possibilities with this material. As a general rule, if proper heat can be maintained during the processing, the size

TABLE II*

Comparative Spinability Ratings of Metals

Aluminum (Type 2S-0)	1.00
Zinc	.94
Steel (Cold rolled deep drawing)	.91
Copper (Cold rolled annealed)	.87
Nickel	.86
Stainless Steel (AISI-347)	.67

*Compares the most satisfactory metal in each group. Ratings are indicative only. Courtesy Milwaukee Metal Spinning Co.

and gage limitations of magnesium are comparable to that of the other light sheet metals.

In wiring—beading a wire into a rolled edge—*Fig.* 13, use of a wire of the same analysis as that of the material from which the spinning is made is advisable. Otherwise the wire must be protected by some form of coating to prevent galvanic corrosion or precipitation action. Where steel wires are used in conjunction with other metals, especially stainless steel, present practice is to tin the wire and solder seal the bead. Full data on galvanic corrosion of various combinations of metals can be found in the "Materials Work Sheets" which appear each month in MACHINE DESIGN.

To indicate the relative spinning characteristics of various metals, a good overall comparison, TABLE I, is included. The rating 1.00 is given the material in each classification which is best suited and lends itself most readily to forming by cold metal spinning. The lower the rating, of course, the higher the production cost. Figures are based on actual experience and will vary somewhat with design, size, metal gage, handling, etc. In TABLE II the ideal materials of each group are rated in the same manner to show comparative adaptability. Here again variations will be found owing to the characteristics mentioned above.

A great many other less widely-used metals can be specified but are only specified in unusual cases where special properties are necessary because of the special handling technique required and the high material cost. These include gold, silver, platinum, kovar, invar, ilium, and britannia or white metal.

TOLERANCES: During the spinning process the thickness of the metal decreases depending in most cases on the ability of the spinner to control the flow of metal. A good average for reduction in thickness at the edge of deep spun cups is about 20 per cent. In other words, to retain a minimum wall thickness of No. 16 U. S. gage the original sheet should be one of the next heavier gage depending on the amount of reduction which varies with different shapes, materials, sheet thickness and metal tempers. Likewise variations in wall thickness—usually less than 25 per cent on good commercial quality spinnings—are dependent upon both the material and the spinner. Some materials, with proper handling, can be held to within 10 per cent of the original gage.

Gage Variation Affects Tolerances

An excellent example of this effect of gage variation on tolerances is the spinning of a full 24 in. inside diameter hemispherical jacket such as that shown in *Fig.* 7 from stainless steel with a minimum wall thickness requirement of No. 14 U. S. gage. Reduction in thickness at the edge of this shape proved to be such that a No. 10 U. S. gage stock was necessary to assure the required minimum wall thickness. This heavy gage stainless is still beyond the capacity of most spinning lathes and thus the part was not practical. However, a No. 11 U. S. gage plain deep drawing steel substituted for this part brings the job into the ordinary commercial spinning range.

Notwithstanding these normal variations in material thickness, unusually close dimensional tolerances can be held on fitted work whenever it is found necessary. Outside diameter tolerances of plus or minus 1/64-in. are commonly held on small work, plus or minus 1/32-in. on medium sized work, and about plus or minus 1/16-in. on large sizes. Tolerances of plus or minus 1/64-in. are, where essential, generally possible for any sized part without affecting the cost unduly. Less economical, but entirely within the scope of the process, tolerances of plus or minus 0.005-in. can be specified and held. *Fig.* 14 is a good example of a fairly large dust shield where such tolerances have been successfully held in production.

Tolerance requirements naturally should be as liberal as is practicable on overall length or depth as well as on flange squareness as noted previously. However, on length or depth of spun machine parts, a maximum variation of plus or minus 1/32-in. can be held and on occasion, where the design permits, even smaller tolerances can be maintained without excessive difficulty.

Collaboration of the following companies in the preparation of this article is acknowledged with much appreciation: Aluminum Company of America; Benson Mfg. Co. (*Fig.* 1); E. W. Bliss Co. (*Figs.* 5 and 13); Milwaukee Metal Spinning Co. (*Figs.* 4, 6, 7, 8, 9, 10, 11, 12, and 14); Glen L. Martin Co.; National Carbon Co. (*Fig.* 3); Republic Steel Corp.; Spun Steel Corp. (*Fig.* 2); V. E. Sprouse Co.

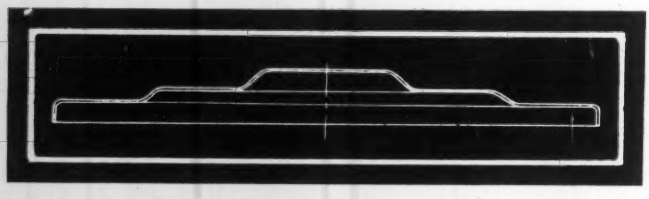


Fig. 12—Above—Smooth curves are an aid to manufacture

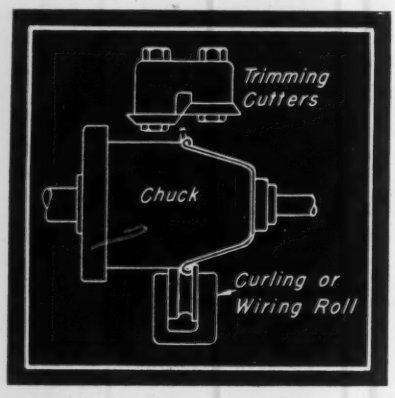
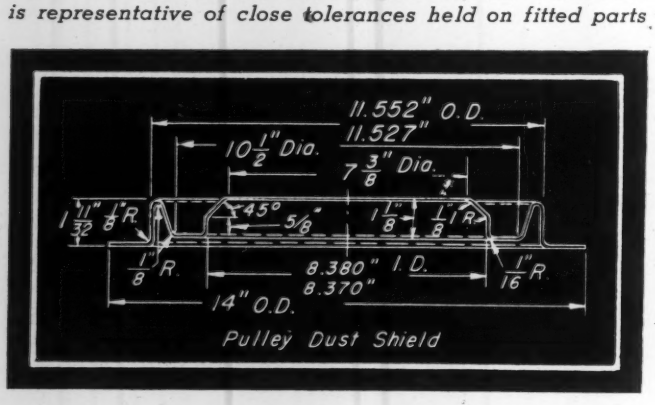
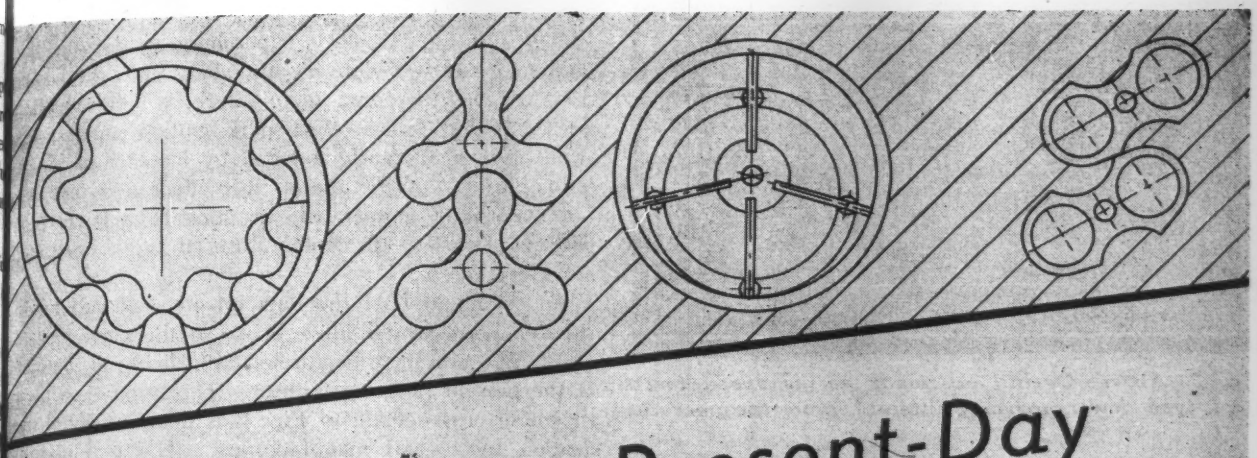


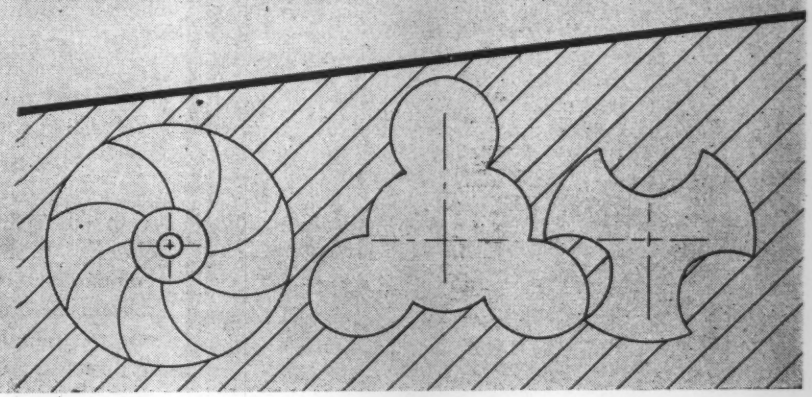
Fig. 13 — Left — A combination trimming and wiring operation

Fig. 14—Below—Spun from 16-gage steel, this dust shield is representative of close tolerances held on fitted parts





Evaluating Present-Day Supercharger Compressors



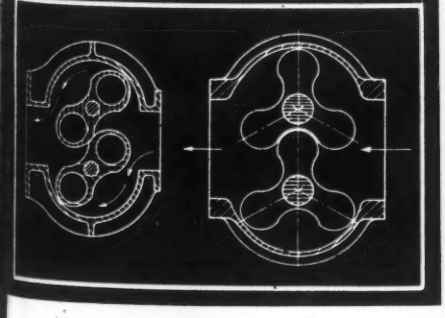
By R. J. S. Pigott
Chief Engineer
Gulf Research & Development Co.

NECESSITY for increasing specific horsepower output, or of recovery of original sea-level horsepower at mountain altitudes, forces the supercharger to front-line consideration. The supercharger has become an essential for gasoline engines in aviation because the loss of power due to altitude, and consequent lowering of ambient barometer, is much more pronounced than for any ground vehicle.

In order to fool the engine into thinking it is still working at ground-level, a supercharger with a compression ratio of 8.5:1 must be provided to do the "kidding" at an altitude of 50,000 ft. For a mountain pass at 15,000 ft, a ratio of 1.8:1 is required for a nonsupercharged engine. If the engine is supercharged to an 8-lb boost at sea-level, it would require a ratio of 2.8:1 for full power at 15,000 ft.

From a paper presented at a recent meeting of the Cleveland section of the Society of Automotive Engineers.

Fig. 1—Two and three-lobe Roots-type blowers are backflow compression devices



The two major classes of superchargers are: Centrifugal or axial turbine types in which delivery pressure, or rather pressure ratio, is dependent on intake absolute pressure and rotative speed with no fixed delivery volume; and positive displacement types in which pressure is not determined by speed, volume delivery of free air is a function of rotative speed, and volume of compressed delivery air is a function of speed and pressure ratio.

Positive blowers can be divided into two types: Adiabatic compression and backflow compression. The familiar Roots class of blower, *Fig.* 1, is a backflow compression device in which there is no change of volume of the charge in the impellers, and consequently no compression. The charge is delivered to the discharged side, at substantially intake pressure, and must be compressed by a backflow of previously delivered air.

The vane-type supercharger, the Elliott-Lysholm screw type, and the writer's internal-gear type, all can be arranged for a true adiabatic compression. These compressors show good possibilities for the higher compression ratios that will be required.

Centrifugal or, lately, axial-flow turbine compressors are just like fans and centrifugal pumps in general characteristics, i.e., at constant intake pressure, delivery pressure is largely controlled by speed. For

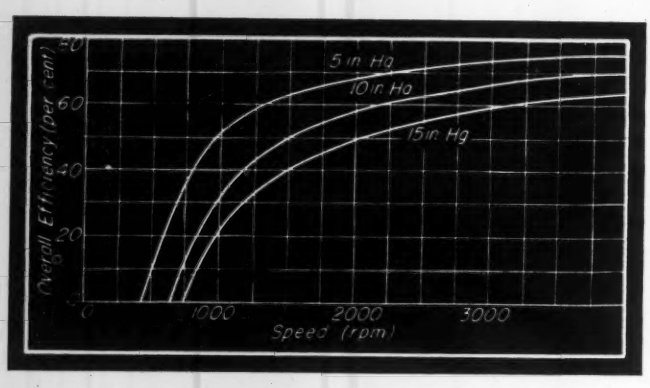
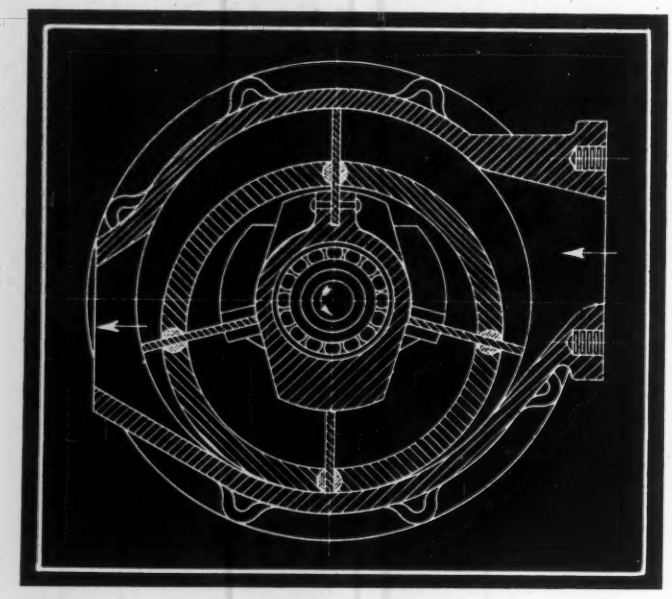


Fig. 2—Above—Overall efficiency versus speed for a Roots-type blower producing different barometric pressures

Fig. 3—Below—Cross section through typical vane-type supercharger, the volumetric efficiency of which is noticeably poor. Internal lubrication is required for vanes



example, if a centrifugal were applied to a truck engine, designed for 8 psi boost at top speed of 2000 rpm, at 1000 rpm the boost would be only one quarter, or 2 psi. The reason the centrifugal has had such wide application for aviation engines is that usually the airplane requires boost only for speeds between cruising and take-off. Since cruising revolutions per minute usually are about 85 per cent of take-off (maximum), the boost can be about 72 per cent of maximum. This is satisfactory for airplanes, as economy rather than power is required at cruising speed. Moreover the kinetic supercharger, either radial or axial, is a very simple machine. But for ground vehicles, the direct-driven centrifugal is almost useless. It is possible that a constant-speed drive could be used, independent of engine speed, for example an exhaust-gas turbine, controlled by gating; in which case constant boost could be maintained at most engine speeds. The penalty is that the supercharger would be considerably off its best efficiency at other engine speeds than that for which the blower was designed.

Efficiency of the supercharger is of considerable importance, since lower efficiency means more parasite horsepower from the engine to get the same boost. Another effect is that of efficiency on temperature of t delivery air. All rotary superchargers put nearly of their losses into delivery air, along with the compr sion heat, as increased temperature, which reduces t density of the charge. For spark-ignition engines, det ation limit is obviously lowered by increase of manif temperature. In the diesel, this effect does not occ but the rise of temperature resulting from lower blow efficiency raises all temperature through the engi cylinder.

An examination of the data on all sizes and kinds superchargers would fill a book, so the capacities fr 350 to 500 cfm have been selected as being in the midd of the present range of interest. The Roots-type blowe shown in cross-section in *Fig.* 1, is made in detail mod fication by several manufacturers. The two-lobe for is the original arrangement, but some builders like th three-lobe form because it curtails pulsations. The tw lobe form has four approximate sine wave deliver charges per revolution, the three-lobe six.

As is common in rotary pumps, the manufacturers us a long face rotor for lower pressure range—in this ca 5 psi—and then simply cut the length of the face f higher pressures so as to keep the bearing loads the sam Thus, the same end plates, bearings and pilot gears ca be used for two sizes, the only change being length o shafts and rotors, and center housings.

Real Slip a Function of Pressure Difference

In the Roots-type blower delivery follows spee closely. It should be pointed out that real slip in rotar compressors is almost exclusively a function of pressur difference, since viscosity of air does not vary much un der the temperatures involved, and speed does not hav a direct influence. But there are two indirect effect that alter the *apparent* slip.

There are dynamic losses in entry and discharge; the centrifugal force of the air in the impeller pockets op poses the inflow, and there are other impact and friction losses from the air diving around corners to fill these pockets of continually changing shape, the result being a very tumultuous flow. As a consequence, the air ac tually trapped in the pockets to be transferred to the discharge is at a lower absolute pressure than at inlet therefore the apparent delivery in free air is reduced. Further, all rotaries except the vane type have some clearance volume—the rotor shapes do not permit o zero clearance. Therefore the discharge-pressure air trapped in the clearance re-expands into the suction side just as in a reciprocating compressor, and cuts down the effective displacement. The net result of these conditions is that the *apparent* slip, as measured by difference be tween free air delivery at inlet and displacement, in creases noticeably with speed. The Roots type is a good blower for low pressures not exceeding, say, 1.6 pressure ratio. Above that, it fades badly. *Fig.* 2 shows overall efficiency of the Roots type.

A vane-type supercharger is shown in *Fig.* 3 (an English design). Although, as pointed out previously, this type can be arranged easily for full adiabatic compression, in this example it does not appear to be laid out for more than $r = 1.1$. The volumetric efficiency is no-

ably poor. Overall efficiency shown in *Fig.* 4.

Because of the nature of centrifugal superchargers, plots of efficiency against constant speed, varying pressure, or constant pressure, varying speed, are of no value. The plot generally used is varying speed, pressure and delivery at best efficiency, which usually is accomplished in testing by employing a thin-disk orifice on the discharge line. Since this condition is practically what obtains in application to an engine with geared drive, the plot shown in *Fig.* 5 is satisfactory. But it is perfectly obvious that the centrifugal would not be of much use on a truck engine, where reasonably constant boost is wanted at widely varying engine speeds.

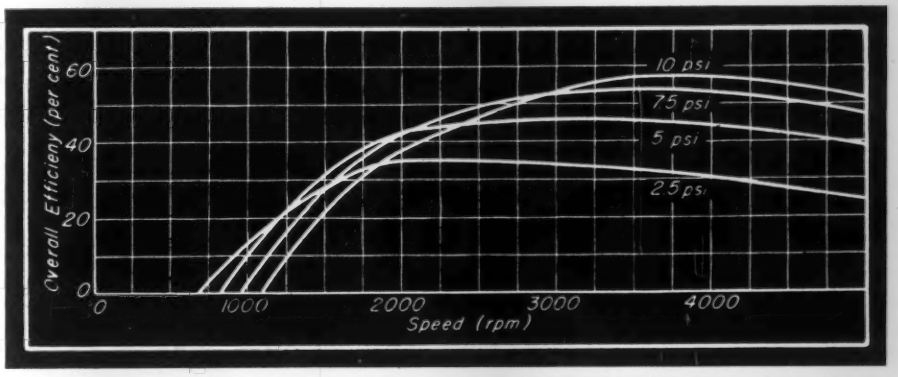
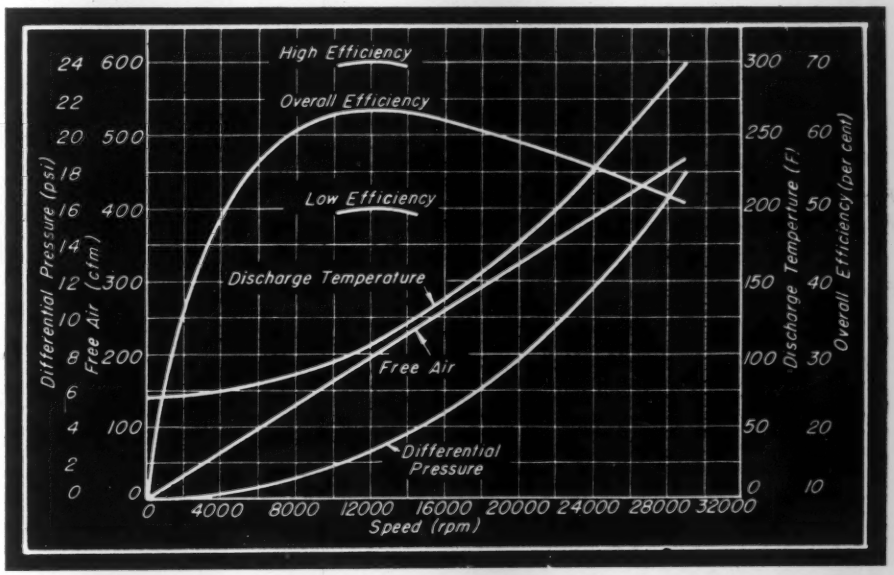


Fig. 4—Above—Curves show overall efficiency versus speed for a vane-type supercharger. Efficiency is inferior to that of the Roots type

Fig. 5—Below—Data on centrifugal superchargers with 9-inch impellers. Overall efficiencies were obtained from several commercial designs in this size range. Performance of centrifugal superchargers is greatly affected by their size



Efficiencies Vary

In *Fig.* 5, a low of 50 per cent overall efficiency, found in several commercial designs, is shown. Only one reached 70 per cent in this size range. It is a fact, just as in centrifugal pumps, that the efficiencies of various designs can vary over an appreciable range. In general this is not so much the case with the positive blowers. It should be observed also that size affects kinetic devices more than it does positive displacement devices. It is relatively easy to make nearly as efficient a 300 cfm positive blower as one of 1200 cfm, but it is a tough job to make a small centrifugal blower approach a big one.

Shown in *Fig.* 6 is the shape and arrangement of the screws in the Elliott-Lysholm supercharger. Overall efficiency for a 500 cfm units is shown in *Fig.* 7. The machine for which the efficiency was plotted had a fixed compression ratio of 1.3.

Another design, similar in general characteristics, is the P. L. supercharger developed from the writer's internal-gear pump, shown cross-sectionally in *Fig.* 8. Overall efficiency is shown in *Fig.* 9. The supercharger has a fixed compression ratio of 1.68, which accounts for the sharp fall-off in overall efficiency at 2.5 and 5 lb. The blower is then overcompressing considerably, and would perform more like the higher pressure lines, if designed for say $r = 1.3$.

Both the Elliott-Lysholm and P. L. superchargers can be laid out for any reasonable compression ratio, to suit the range of pressures on which they are to be used. This provides a large flat efficiency range. The P. L. supercharger described was intended for use on 8 to 18 boost.

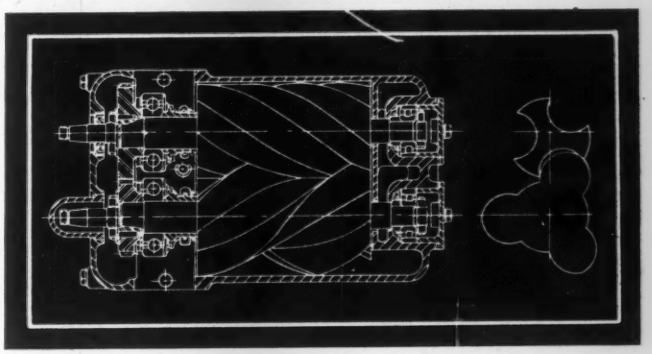


Fig. 6—Shape and arrangement of screws in Elliott-Lysholm supercharger which offers a large flat efficiency range

Summing up, the centrifugal supercharger is structurally simple, but is not adapted to furnishing approximately constant boost for an engine at widely varying speed. It has had an entirely justifiable growth in use for large stationary diesels running at constant speed, because it can be adapted to such cases. Its efficiency

is much improved by size. One objection to its use on road vehicles is the high rotative speed combined with small shafts and bearings.

The Roots blower is a simple, sturdy device, well adapted to the needs of road vehicles, and has had a good development for both diesels and spark-ignition engines. But it is limited in pressure range, being satisfactory up to 7.5 psi and usable at 10 psi, but no higher.

Vane-type superchargers have had a little development in Europe but none here. They do not, in designs so far developed, show efficiency as good as the Roots type,

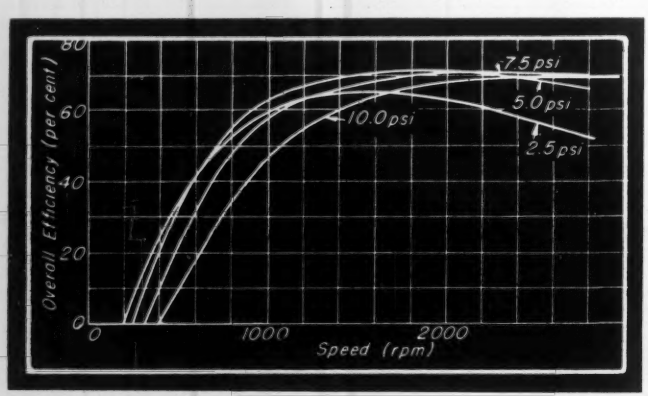
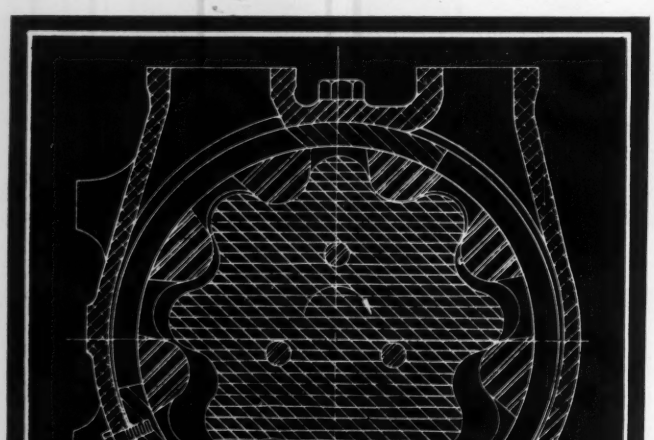


Fig. 7—Above—Overall efficiency versus speed of an Elliott-Lysholm supercharger developing various pressures

Fig. 8—Below—Cross section through P.L. supercharger which is a modified type of internal gear pump



and in general have more bearing surface to be lubricated and more complex design. There are ten ball bearings in the design of *Fig.* 3, two for each vane and two for the main shaft. Internal lubrication, required for the vanes, definitely is objectionable for a diesel. If the vane type is to succeed, it will probably need a considerable increase in number of vanes.

Best efficiency of any development so far is offered by the Elliott-Lysholm. It is simple and can be operated at high speeds if desired. While the development ov a period of ten years took place mostly in Sweden, w understand it is about ready for production here.

As for the P. L. supercharger, it has had little develo ment, but shows excellent possibilities. The fact th the first model showed overall efficiencies of 64 pe cent at 10 psi in a 320 cfm size is sufficient justificatio for presenting it. This type also does well at high speed

All of the positive displacement blowers can b matched to engine demand fairly well, as the engine also a positive displacement device. But since, in addi tion to inlet losses, similar to those in the induction sid of the engine, the blower has a considerable slip from the pressure difference, the delivery of the blower doe not match the engine demand at constant boost pressur at all speeds. What happens is that the boost will ad just to match the delivery of the supercharger to th displacement of the engine. Since what we are after i maximum brake mean effective pressure at full throttle the pressure *inside the cylinder* should be constant Therefore the manifold pressure, or boost, should in-

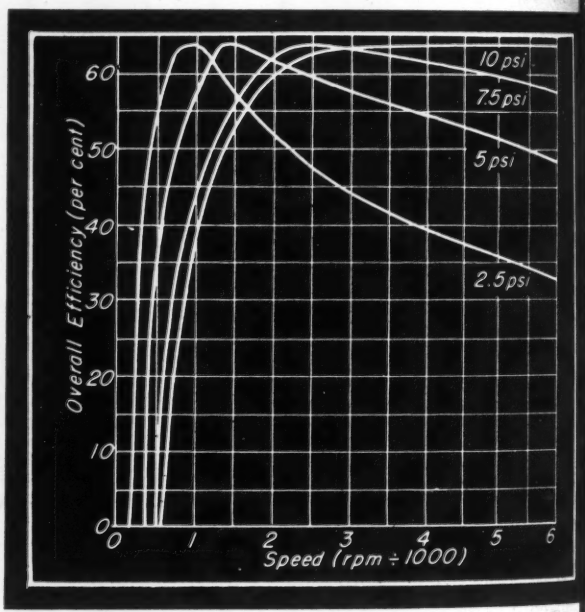


Fig. 9—Overall efficiency versus speed of a P.L. super charger developing various pressures

crease with speed. An engine designed for 8 psi boost at maximum speed of 2400 rpm would require only about 6 psi at 1000 rpm to get the same pressure in the cylinder. The positive blowers can meet this situation quite well, but a high volumetric efficiency is always desirable. All the above is based on full throttle. For part loads at any speed, the output can be reduced in spark-ignition engines by throttling the suction side of the blower.

For the diesel, this expedient is not necessary, as the injection takes care of the situation completely. For stationary diesels at constant speed, the centrifugal will continue in a favorable position. For automotive variable-speed operation, the Roots does well at the lower boosts, but for the higher pressures likely to be used the Elliott-Lysholm and the P. L. gear type, should serve better than any design so far offered.

Fig. 1—Precision performance has been achieved with low-cost parts in this modern business machine

Achieving Precision Performance With Low-Cost Parts

By R. L. Stone

Chief Engineer
The SoundScriber Corp.

ORDINARILY, precision machines require precision parts. In the modern business recorder shown in *Fig.* 1, however, precision performance is achieved with the use of mass-produced, commercial parts. As might be expected, this achievement has been the result, primarily, of careful design.

Basic requirements of a modern business recorder include: Simple and foolproof operation of both the recording and reproducing equipment; low record cost per unit of recording time; compact, durable and easily handled records that can be logged, filed and mailed; various conveniences such as instantaneous start-stop, instantaneous step-back, logging systems, and comfortable listening devices for the reproducing machine used by the typists.

The majority of instantaneous recorders

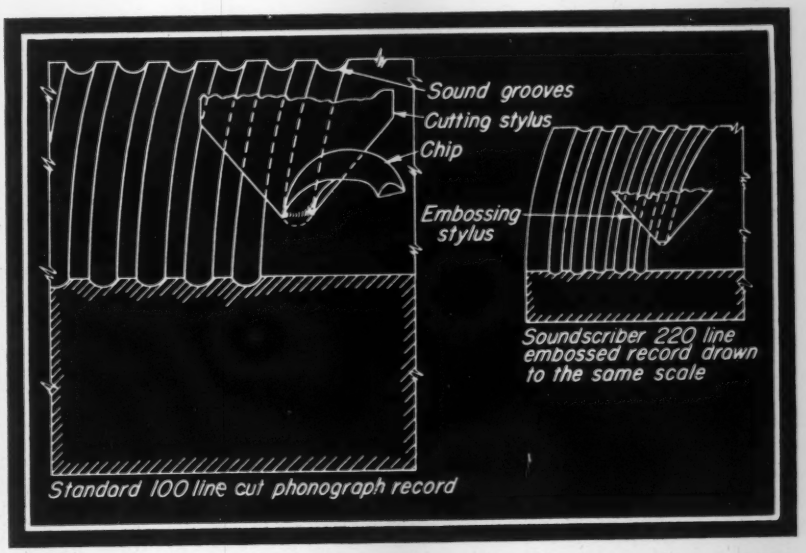


Fig. 2—Comparison of cut and embossed types of recording grooves. Embossed grooves are more closely spaced, create no chips

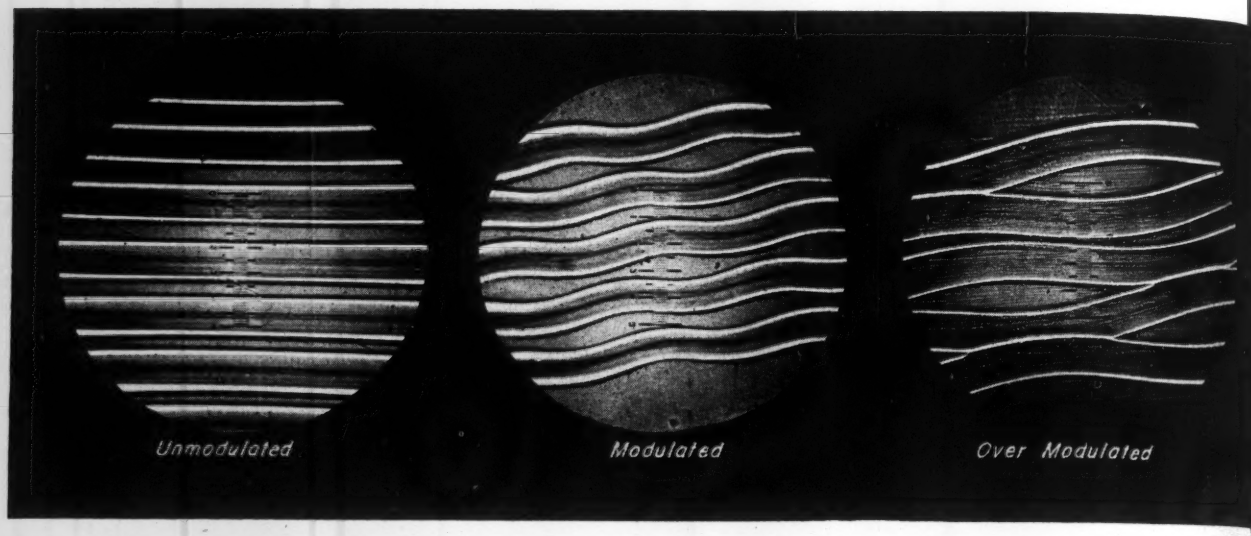


Fig. 3—Above—Embossed grooves und microscope. They are 0.0045-inch center-t center, 0.003-inch wide and 0.0004- inch de

Fig. 4—Below—Drawing of primary mechanic units of machine shows how flexible couplin and spring suspension isolate motor vibrati

use the cutting process. In this, a thread or chip is removed from the record just as is done in a lathe or other type of machining operation. Examples are the wax-cylinder type of dictating machine and the acetate-disk type of recording machines. In these, stylus pressures, stylus angles and stylus renewal, together with the thread removal problem, are factors that must be given careful consideration.

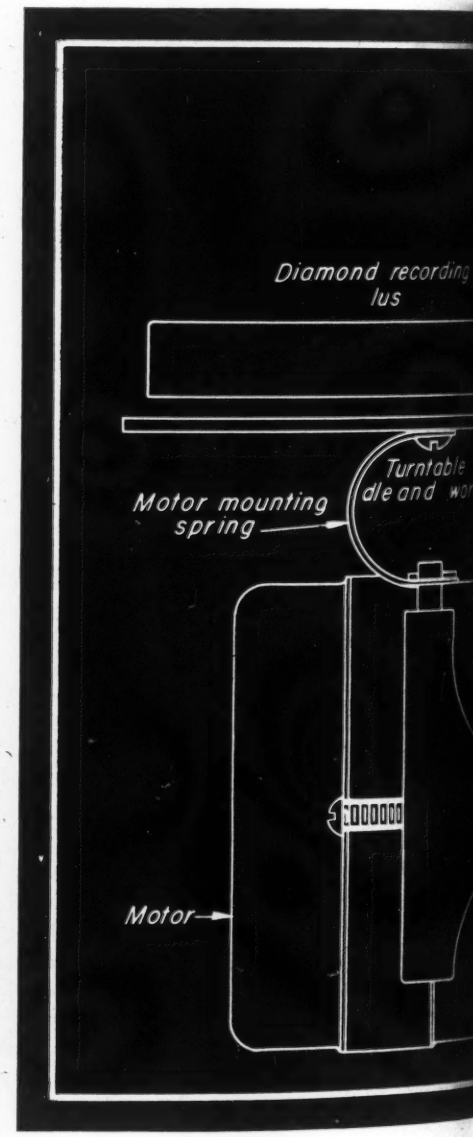
To eliminate various inherent difficulties associated with these factors, the machine herein discussed was designed to produce the sound groove by embossing rather than cutting. In the embossing process a permanent, diamond recording stylus is used. Diamond angles and stylus pressures are not critical and of course no chip or thread is removed from the disk during recording. A comparison of cut recording grooves and the embossed type is pictured in *Fig.* 2.

Advantages Offered by Disk-Type Record

The decision to use the familiar disk-type record was based on the utter simplicity of handling a disk, the speed with which it can be changed, its permanence, filability, mailability, and compactness. To achieve minimum cost of this recording medium in terms of cents per hour, it was essential to depart in many respects from conventional practices used in phonograph recording. In the first place, the turntable speed chosen was 33 revolutions per minute as compared to 78 revolutions per minute on conventional phonograph records.

Secondly, the spacing of the grooves was changed from the standard commercial spacing of 100 lines per inch to 220 lines per inch. Third, the thickness of the record adopted was 0.010-inch instead of the standard thickness of about ⅛-inch. Because of the extremely close groove spacing used, the record (7 inches in diameter) plays for fifteen minutes on each side compared with approximately five minutes on each side for a twelve-inch diameter record of the familiar phonograph type. As a result of this long playing time on a small record, both compactness and the desired low recording cost per hour have been achieved.

The embossed sound track or groove employed with this system has a width of 0.003-inch and a depth of only 0.0004-inch. Thus it is essential that the shape of the diamond stylus be held to truly microscopic tolerances if the uniform shape of groove essential to good playback tracking and quality is to be maintained. Center-to-center distance between adjacent grooves is 0.0045-inch and, since the groove width is 0.003-inch, it will be apparent that permissible sideways undulations of the recorded grooves are restricted to swings on the order of 0.001-inch to either side. Excursions of this magnitude represent the maximum recording volume that can be put on



e disk without having the sound from one groove inter- re with that from the next. Spacing of the embossed ooves as they appear modulated, over-modulated and modulated, is clearly shown in the microphotographs *Fig.* 3.

Any extraneous vibration present in the machine, from hatever source (such as the turntable driving motor), so will register in the groove and be heard on playback objectionable noise. Therefore, insofar as possible, all brations must be kept from reaching the turntable. Again, riations in the spacing of adjacent grooves on the order 10 per cent (0.00045-inch) would restrict the permis- ble excursions of the recording stylus by approximately per cent. Thus it will be seen that the mechanism hich feeds the recording arm across the disk during re- rding must be extremely accurate, with irregularities of ed being held to less than 0.0004-inch.

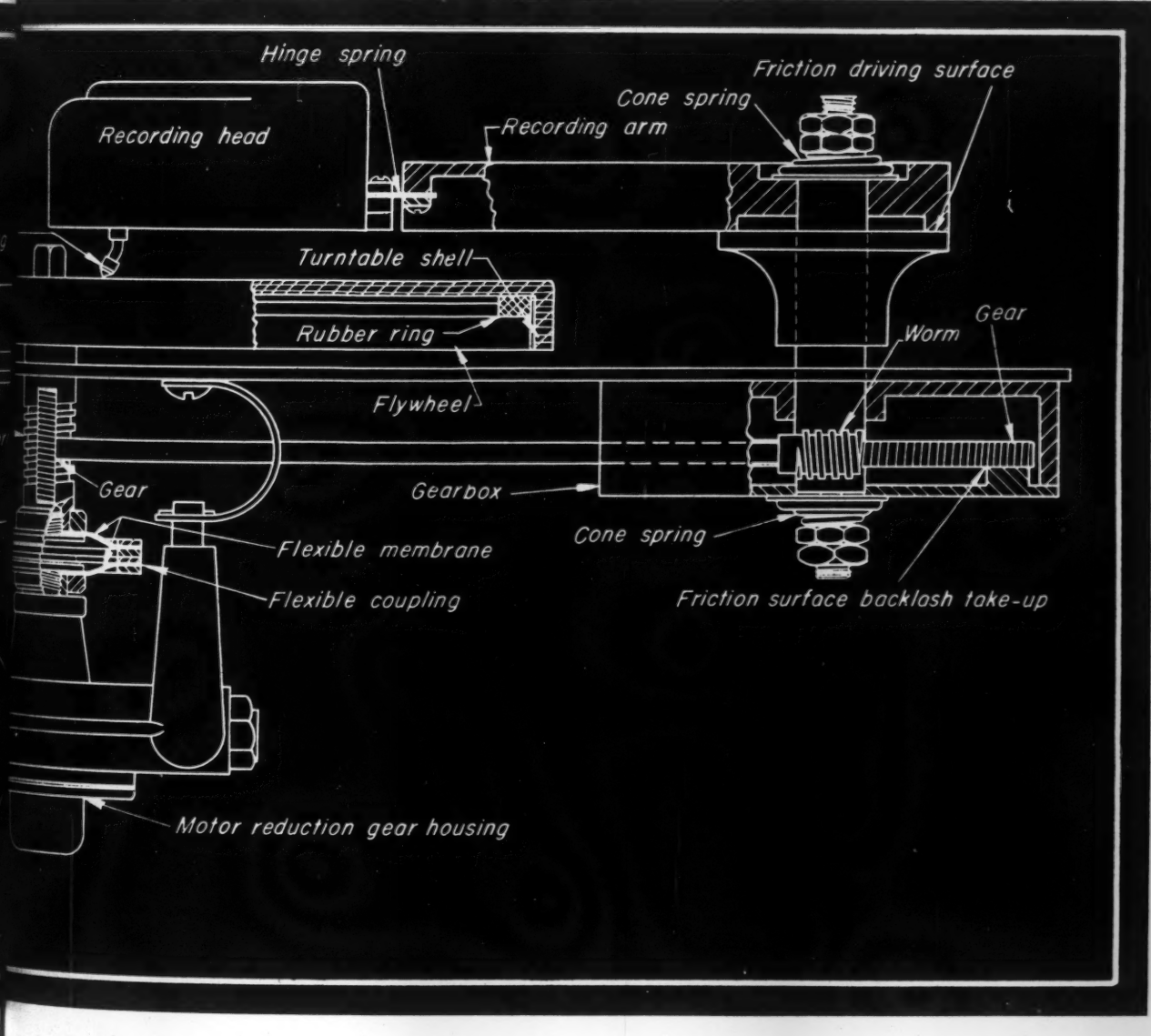
How the turntable and recording-arm drives are de- igned is shown in *Fig.* 4. The motor, its supports, and e driving coupling which connects the motor to the turn- ble, comprise a balanced, mechanical vibration-filtering ystem. Surprisingly enough, the high-precision feed of e recording arm is achieved without resorting to the em- ployment of ultraprecision parts such as would ordinarily be required.

By means of a built-in, worm gear reduction unit the speed of the motor which drives the turntable is brought down from 1650 to 33 revolutions per minute at the output shaft. Because the reducer is lubricated and sealed at assembly, it needs no further lubrication for the life of the equipment.

Coupling Serves Dual Purpose

As *Fig.* 4 clearly shows, the output shaft of the motor is coupled to the turntable by means of a fabric dual-membrane coupling which provides the limited degree of universal-joint action required between the motor and the turntable spindle. This coupling also serves as an excellent vibration filter, keeping the inherent vibration of the motor from reaching the turntable. To minimize the transmission of vibration from the motor to the chassis, the motor unit is suspended from the chassis on curvilinear flat steel springs.

First stage of the recording arm drive is the speed reduction effected by the bronze worm gear meshing with



the worm cut on the turntable shaft. A drive shaft connects this gear with another worm gear reduction unit. The gearbox of this latter unit also contains a worm and a large bronze worm gear which is force fitted to a substantial spindle having a collar that supports the recording arm and head assembly.

Bearing in mind the extreme accuracy demanded of the recording-arm feed by the stringent tolerances mentioned above, it will be seen that even the slightest amount of backlash in the gear train from the motor to the arm spindle would be intolerable. Had precision gears been employed they would wear in time, so they were not a logical solution of the problem. Of course they could have been mounted on adjustable centers, but this not only would have added to the cost of the machine but would have necessitated frequent adjustment by skilled servicing personnel. If the drive had been two-directional over a limited number of revolutions, it might have been possible to eliminate backlash by loading the train with a spiral spring. However, since the drive is unidirectional, such an expedient was not feasible.

The design which licked this backlash problem is quite simple, added not one iota to the cost of the machine and permitted the use of standard commercially cut gears. Here's how it is done: The bottom surface of the large worm gear mounted on the recording-arm spindle rides on the cover of the gearbox against which it is held under pressure by a compressed conical spring. Thus there is a

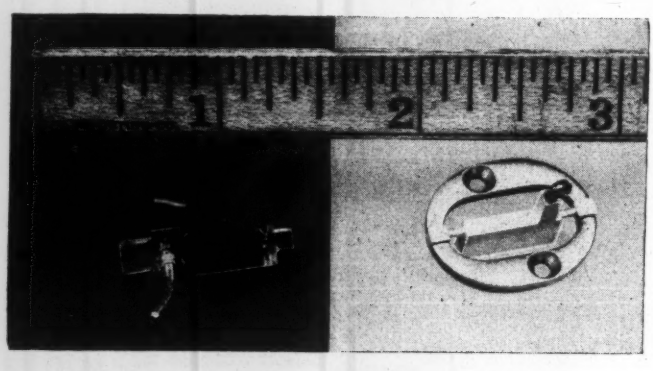


Fig. 5—Coil and stylus of playback head are mounted in Lucite frame (left). Recording armature is in metal frame

constant frictional load on the whole gear train and backlash is effectively wiped out irrespective of the amount of wear on the teeth of the gears.

This frictional-loading principle is further utilized in mounting the arm itself to the spindle. While the arm must be driven positively by the spindle, it must also be designed to permit swinging it across the disk to any desired position (for example, when the arm is swung back to the "start" position for each new recording). Both requirements are met by mounting the arm on the spindle so that its lower surface is pressed against the spindle collar by the compressed conical spring. The friction between the arm and the driving collar is factory adjusted to be considerably less than that between the large worm gear and the gearbox cover. Therefore, when the recording arm is repositioned it will not disturb the gear train and will feed instantly wherever it is placed on the disk.

It will of course be seen that the recording head must at times be lifted off the disk. However, while the des had to permit lifting the head, lateral movement of head, no matter how minute, could not be tolerated cause it would interfere with the accuracy of the gro spacing. In addition, free lateral play in the record head pivot would permit the stylus to vibrate the he during recording and result in poor recording of sou This problem was solved by simply fastening the head a arm together with a thin, flat steel spring, utilized as hinge.

The recording surface of the turntable is a hard smoo molded bakelite shell (see *Fig.* 4) which acts as an an for satisfactory embossing of the thin plastic disks. T bakelite shell is supported on the heavy die-cast turntab (which also serves as a flywheel) by means of a spon rubber ring which further serves to insulate the turntab shell from any vibration present in the chassis.

Refinements Also Required for Playback

Reproduction (playback) from the embossed, close spaced, shallow grooves similarly involves a number refinements and innovations in the reproducing arm a head mechanism. The playback stylus is a permane sapphire jewel, ground and polished to a microscopica accurate radius of 0.0018-inch. This stylus is mounted an aluminum shank and the shank is cemented into extremely light Lucite frame in which is mounted t moving coil of the dynamic playback head (*Fig.* 5). M chanical resistance to lateral movement at the stylus only a fraction of that of conventional phonograph pic ups and this is essential if good tracking of the shallo grooves is to be obtained. As a result of this low mecha ical impedance, weight required on the playback stylus f satisfactory tracking is correspondingly reduced. T weight used is approximately ½-ounce compared wi three to four ounces on some conventional phonograp pickups. With this extremely low weight, record wear negligible and the playback arm may be skidded free across the grooves to any desired point on the record f instantaneous playback without any harm to the grooves.

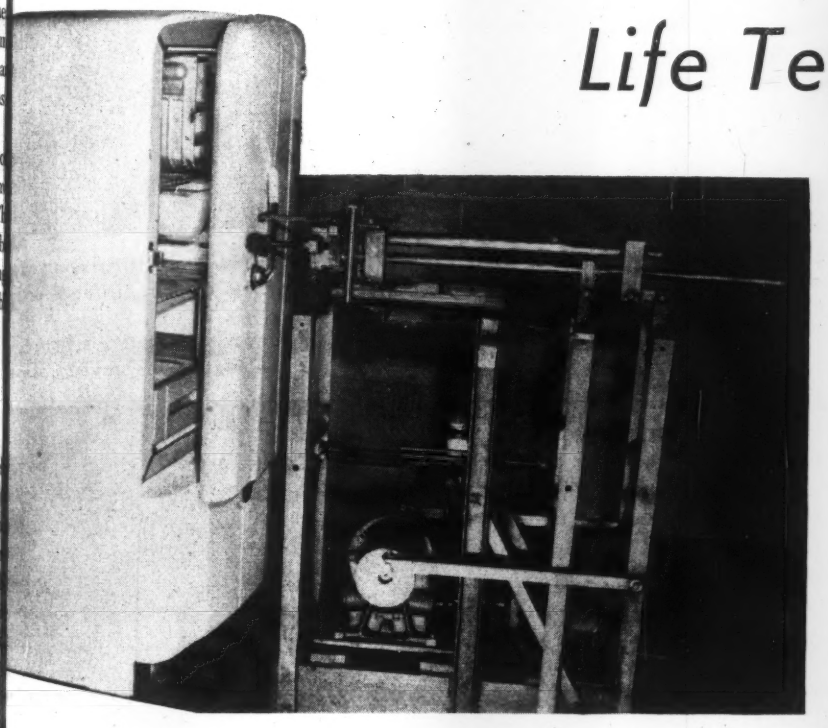
The playback arm itself is pivoted on a single harden steel ball and is counterweighted so that minimum fri tion exists to be overcome by the stylus as it tracks the groove. For the sake of simplicity in positioning th pickup to the desired groove, the pickup is not on m chanical feed, but is fed by the groove just as in the ca of a conventional phonograph.

Another unusual feature of the playback arm is th method employed to neutralize the frictional force cr ated at the arm pivot. This force is effective sideways the stylus and, even though it is exceedingly light, would tend to interfere in a limited manner with tracki if it were not neutralized. Neutralization is achieved b fastening a light tension spring between the arm and bracket so that the pull of the spring just balances o the sideways force created by friction at the pivot.

In ordinary dictating applications, recorded mater has to be transcribed to a typewritten page and the typ has a transcribing machine. This is similar to the recor ing machine except that it has no recording arm and

(*Concluded on Page* 178)

Improving Design through Life Testing



By R. E. Peterson
Manager, Mechanics Dept.
Westinghouse Research Laboratories

LET US say that we have produced a new electric motor, or a new engine, or a new washing machine. We bring it to the test floor, put it through its paces, measure and record everything imaginable, and find that the device behaves satisfactorily. One further question remains—will it repeat this performance, starting and stopping and cycling, year in and year out for a satisfactory life? To attempt to settle such a question, life tests are devised to test component parts, usually with the idea of crowding a life of cycling into a reasonably short testing time.

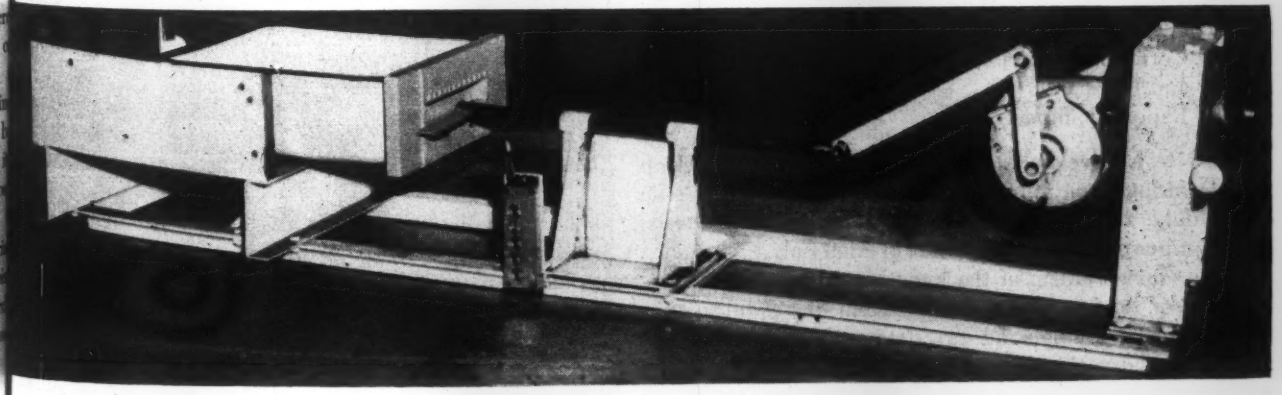
Based on a paper presented at a symposium on life testing held by the American Society for Testing Materials in Detroit. The author was recently appointed a member of the new ASTM administrative committee on accelerated service testing.

Consider a simple operation such as opening and closing a refrigerator door. Merely because the door works well for a few times does not mean that it will function satisfactorily over a period of years. The spring in the latch could break due to fatigue, the latch and hinges could wear excessively, the sealing could become inadequate, in fact quite a number of things could happen in this very simple case. In place of a housewife opening and closing the door repeatedly, we make a machine, *Fig.* 1, which performs the same operation successively, 24 hours a day. In general a refrigerator door is not just closed, but is slammed shut, and the machine is made to take this into account. The machine operates at 15 cycles per minute and an equivalent life of 15 years is covered in about 12 days.

In a similar test for an automatic washing machine door which drops to a horizontal position, a crack appeared at each of the hinge attachments. As a result the structure

Fig. 1—Above—Refrigerator door-slamming machine, an example of a device for life testing domestic appliances

Fig. 2—Below—Tray-sliding apparatus for checking durability of finishes and materials of refrigerator trays



was redesigned and satisfactory performance was assured by further tests. Inasmuch as appliances are produced in large quantities when they are produced at all, it makes an enormous difference whether the crack appears during a preliminary 12-day test or later on in thousands of units all over the country.

In *Fig.* 2 is shown an apparatus to simulate the repeated sliding of a refrigerator tray or drip pan, as a check on durability of finishes, materials, and the design of supports.

Sometimes it is possible to cycle the entire device in such a manner as to answer the main questions in a reasonable time. For example, a battery of automatic washing machines is put through successive cycles of filling, washing, draining, rinsing, and spinning, continuously on a 24-hr basis, the equivalent of 10-year life being attained in about 2½ months. In this case any corrosive effects are not properly accounted for and precautions must be taken to prevent troubles due to this cause.

In *Fig.* 3 is shown an apparatus for fatigue testing a turbine blade at high temperature. The blade is heated electrically to simulate the temperatures and gradients of service. Variable stress is applied by means of an adjustable eccentric. An intermediate spring cage serves as a load-measuring device and also permits large motions at the eccentric which reduces wear errors to a negligible amount. Centrifugal force is simulated by a vertical pull mechanism which is flexibly connected. A fatigue crack in a steam turbine blade root as produced in the laboratory apparatus just described is shown in *Fig.* 4. The apparatus is now being used for testing gas turbine blades. Actual life tests of blading have been made in an experimental turbine, with vibration amplitudes indicated by an ingenious optical method. These methods have led to important improvements in blade utilization and performance.

Duplicating Service Conditions

In general, life tests should duplicate service conditions as closely as possible. Since it is easy to overlook an important variable, a great deal of thought should be put into the design of any particular life test, and service data should be methodically collected as a guide for future tests.

In analyzing life testing in terms of its fundamental elements, it will be noticed that time and cycling are the important characteristics. This leads to consideration of the following conventional tests:

Group A
1. Fatigue
2. Creep (including relaxation and creep-rupture)

Group B
3. Wear (including erosion and fretting)
4. Corrosion, deterioration of nonmetallic materials and lubricants
5. Repeated impact.

These tests have been divided into two groups: Group A, comprising quantitative tests, capable of giving specific design data; and Group B, which includes qualitative tests, useful primarily for a comparison of materials.

If the main problem of the hypothetical new machine is in the second group, say a wear problem, the problem cannot be solved by looking up data and calculating the answer; nor can the desired design data be obtained by making a conventional test. A life test simulating actu conditions as closely as possible is very much in order f problems of this kind.

If the problem is in the first category, fatigue or cree there is at least a possibility of predicting satisfactory per formance. But even if the problem is relatively simpl

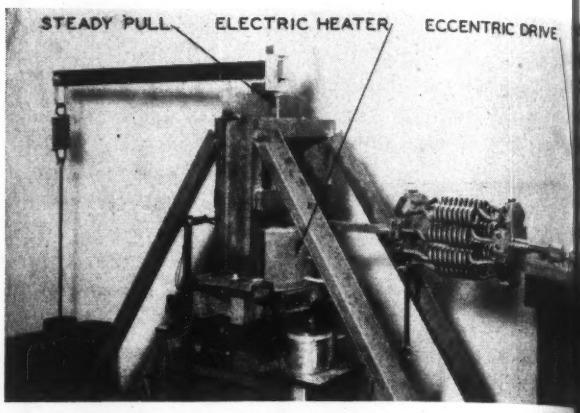


Fig. 3—Above—Turbine blade fatigue-testing setup whi simulates temperature, vibration and centrifugal effe

Fig. 4—Below—Crack produced by laboratory setup sho in Fig. 3. Result points the way to improved desig

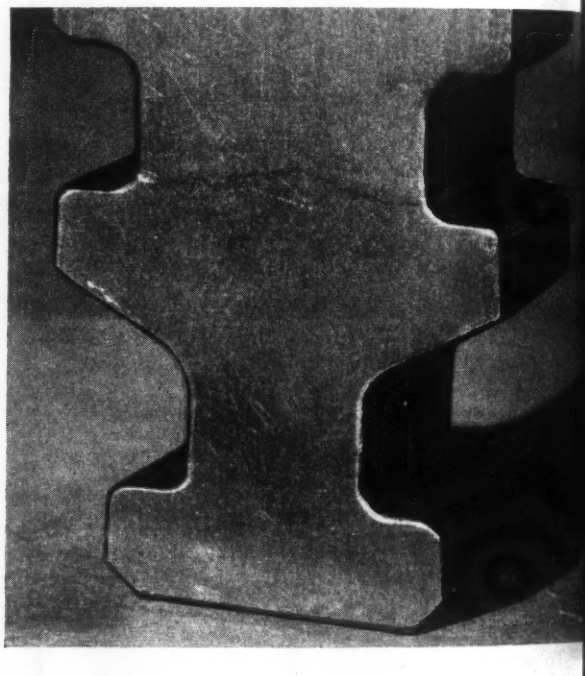
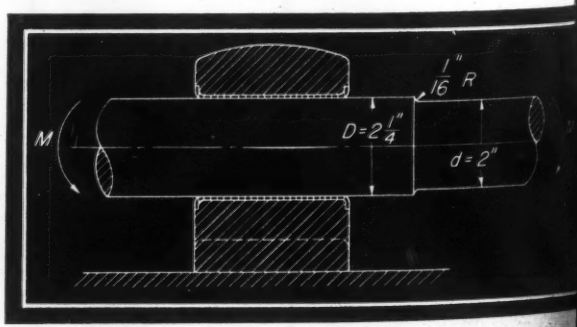


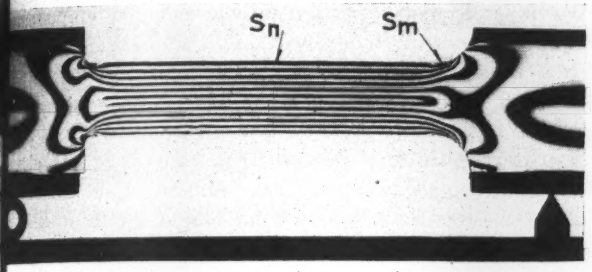
Fig. 5—Below—Example of a rotating shaft subject bending, used for fatigue problem discussed in artic



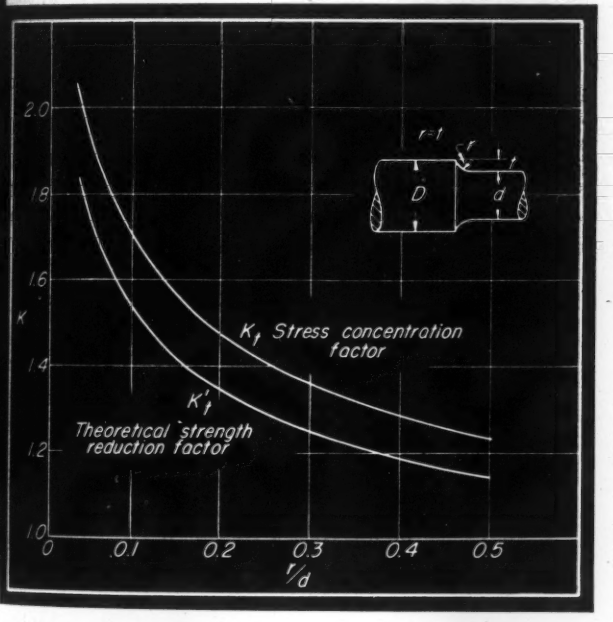
re are more considerations involved than is generally preciated. Such a problem will be examined in detail.

Suppose that a critical section of the device is the fillet tion of a rotating shaft in bending as shown in *Fig.* 5, material used being normalized SAE 1035 steel with a minal endurance limit of 34,000 psi.

As is well known, a fillet causes a local increase of stress, g. 6, as evidenced by the crowding of the photoelastic

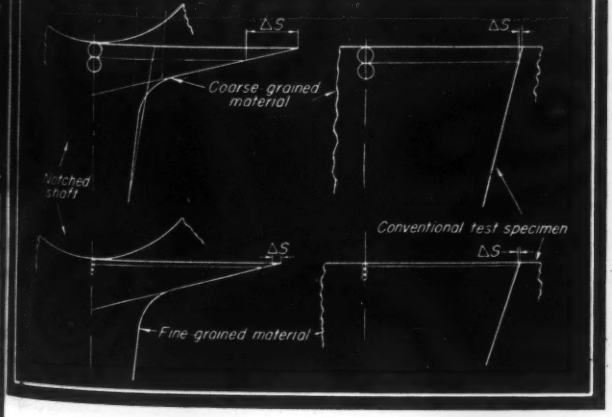


g. 6—Above—Stress concentration effect determined photoelastically. Stress is maximum at fillet



ig. 7—Above—Fillet factors for circular shafts. Lower curve takes account of combined stress

ig. 8—Below—Comparison of stress gradient effects for a notched shaft and a conventional test specimen



fringelines in the fillet as compared to their even spacing in the straight part of the bent bar where the stress distribution is linear. This local increase of stress is expressed technically in terms of a stress concentration factor, K_t = maximum stress/nominal stress. A curve of such factors, determined photoelastically, is shown in *Fig.* 7 (upper curve).

In a shaft fillet or groove there is, in addition to the stress in the bending plane, a stress at right angles in the circumferential direction. Where there is more than one stress we need a strength theory. It has been found that for ductile materials the shear-energy theory fits available fatigue data reasonably well. Since the two stresses mentioned are related by a constant we can figure a "theoretical strength reduction factor", K_t' (lower curve of *Fig.* 7), which takes account of both stress concentration and strength theory. From this curve we find that for the given shaft dimensions ($r/d = 1/32$), the value of K_t' is 1.85.

We are not yet ready to finish this problem, which as mentioned before is a relatively simple one. We still must consider the material, for it is known that high-strength heat-treated steels are highly sensitive to notch effects, while normalized steels are less sensitive. This is usually expressed by a "sensitivity index" q defined as follows:

$$q = \frac{K_f - 1}{K_t' - 1}$$

where $K_f = S_e/S_n$ = ratio of endurance limit without fillet to nominal endurance limit with fillet. S_e is obtained from tests of conventional fatigue specimens preferably ½-inch diameter or larger. K_t' = theoretical strength reduction factor.

As can be seen from the equation, q is defined in such a way that for no notch effect in fatigue ($K_f = 1$) $q = 0$, and for full theoretical notch effect ($K_f = K_t'$) $q = 1$. This gives a scale from 0 to 1 for evaluating notch sensitivity.

It is unfortunate that we do not have a better term than "sensitivity" since this connotes a mysterious characteristic possessed by materials. It will be worthwhile to examine the variables involved.

A fillet, notch, or other form of stress concentration introduces a steep stress gradient, *Fig.* 8, at the surface as compared with a conventional bending test specimen. With a material so coarse-grained that near the fillet surface where the stress gradient is high the stress drops, say, 25 per cent in crossing a grain, the same fatigue behavior would not be expected as with a conventional testpiece where the drop in stress across a grain is relatively small. In the former case it should be more difficult for a crack to get started and to propagate itself; this is confirmed by testing experience. A notched specimen of coarse-grained annealed or normalized carbon steel usually will not be reduced in fatigue strength as much, percentage-wise, as will a similar specimen of fine-grained heat-treated steel. These results, then, seem explainable in a general way on the basis of grain size and stress gradient. There may also be present a cold working effect but, in any event, stress gradient is a logical parameter to use in evaluating the effect of various notches or "stress raisers".

It can be shown that over a considerable range the stress gradients of such "stress raisers" as fillets, grooves, and holes are approximately proportional to $1/r$. Available

data therefore have been plotted on charts of q versus r, *Fig.* 9. This type of curve is a theoretical one based on: (1) Failure at a constant depth (0.002-in. for SAE 1020); (2) an average $K_t' = 1.8$; (3) curve shifted laterally so that when $r = 0$, $q = 0$.

A summary of notch-sensitivity curves of the type just described is given in *Fig.* 9. The top curve represents fine-grained quenched and tempered steels, the middle pair of curves represent normalized steels of medium grain size, and the bottom curve (which carries a question mark because of insufficient data) represents a very coarse-grained steel (as rolled). These curves, then, may serve as a guide for estimating notch sensitivity, at least until we have something better. It should be noted that the curves are not applicable to deep grooves or sharp fillets, which incidentally should be avoided in design.

We are now ready to return to our illustrative problem and complete it. We see that for $r = 1/16$-in. we have $q = 0.82$ for SAE 1035 steel. The maximum nominal bending stress which the shaft can carry is then

$$S_n = \frac{S_e}{1+q(K_t'-1)} = \frac{34000}{1+0.82(1.85-1)} = 20{,}000 \text{ psi}$$

As far as this simple machine element is concerned we can say that we understand it well, and if our operating stresses are substantially lower it should not be necessary to make life tests. Unfortunately, our knowledge is so limited that we cannot often make such a confident prediction. But progress is being made and we are getting reasonable checks on increasingly difficult problems, such as turbine blade fastenings, gear units, etc.

So far only one of the two quantitative tests mentioned, namely, fatigue has been discussed. Creep data are of interest in steels primarily at elevated temperatures, but for die castings and other soft metals important effects occur at room temperature. Space will not permit an extensive discussion of the many aspects of the subjects of creep, relaxation and creep-rupture. In the first two cases, integrated effects of the behavior of large masses of grains are involved and therefore analytical methods are appropriate as a means of interpreting and extending test data. In fact, if we are trying to predict how much a red-hot part inside a turbine will creep in 10 or 20 years we must extrapolate by mathematical means from the results of c tests of a few months' duration. It is not a questio whether or not to extrapolate—it is only a questio whether we do it poorly or well, whether we gues whether we use the best available data and analy methods.

In the case of creep rupture (that is, brittle failure a an extended time at constant load and temperature), experimental approach will be the main one for some ti We think of creep-rupture mainly at elevated temperatu but it can occur, for example, in soldered joints at ro temperature.

It will be noticed that in general emphasis has been u a more basic and detailed approach in design applicati of materials. It may be remarked that since a factor safety is always used anyway, refinement in design i waste of time. Such a viewpoint would not be in keepi with modern trends in design. The aviation industry a many others find that it pays to make extensive detail analyses coupled with numerous tests of all kinds. A ne and rapidly growing technical society is devoted entire to experimental stress analysis. In these days is seems pa ticularly characteristic of designers that they are continua asking for more information of a basic nature.

This is not to say that life testing will become obsole For certain problems involving wear, friction, lubricati etc., there is no other way. For many complicated fatig problems a life test is most certainly advisable, but it hoped that as our knowledge increases we will make bet designs quicker and will use life testing as a check design rather than as a cut-and-try procedure.

It might also be added that even now life testing is a plied chiefly to items of large production. It is not possib to life test large generator or turbine rotors, or many ite produced in quantities of one or a small number. We mu rely in these cases entirely on the designer and the mo information he has the better.

In conclusion, it can be said that life testing, field tes laboratory tests of conventional specimens, stress analys and studies or mechanics of materials all have a prop place in the overall picture, and if we wish to make th most effective progress in basic design practice we shou plan our work so that the results obtained in these fields c be correlated in a fundamental manner.

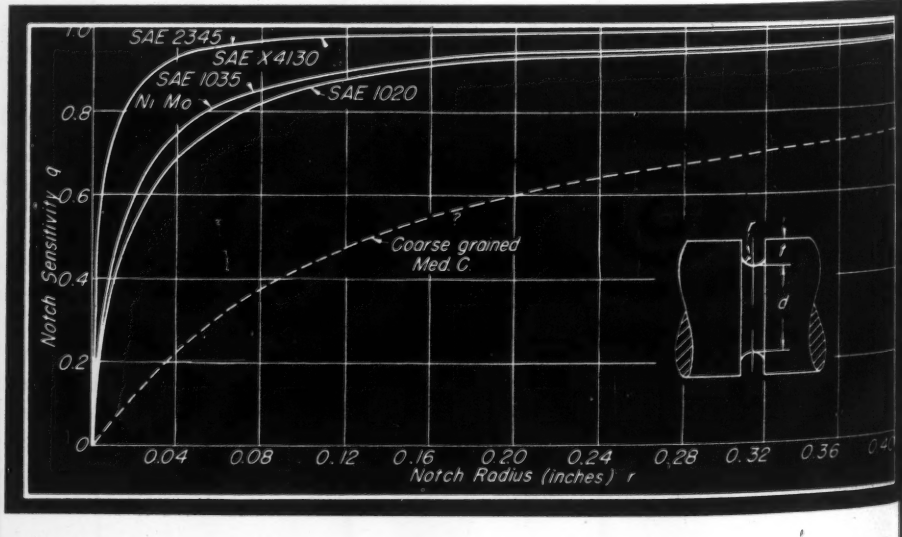
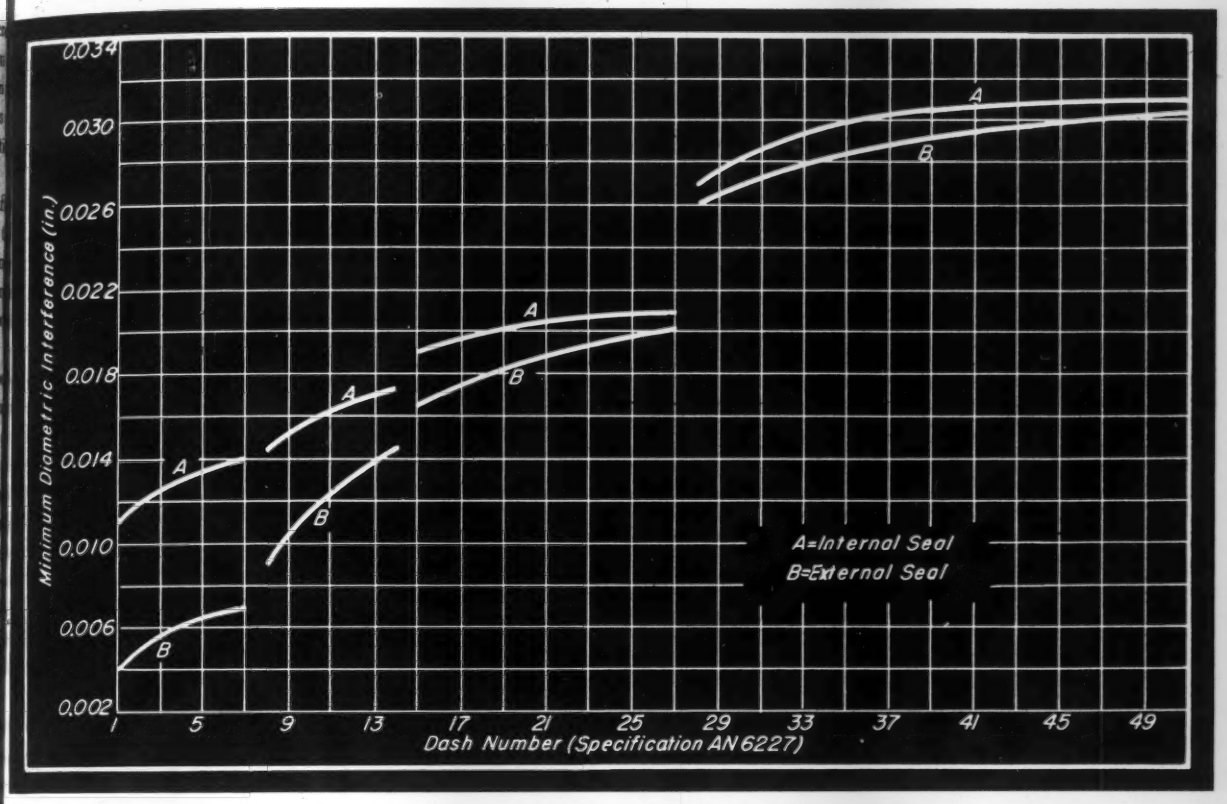


Fig. 9 — Notch sensitivity curves for various materials. Not applicable to deep notches or sharp fillets where t is more than 3 times r



Design Standards Offer Accumulative Savings

By Richard M. Lord

Development Engineer

Pacific Div., Bendix Aviation Corp.

ACHIEVEMENT of full benefits of machine production depends on the use of design standards. This was realized first by Eli Whitney who in 798 astonished U. S. government officials by "tooling p" to make 10,000 muskets which would not be "all ifferent from one another". The feat of turning out nal assemblies of interchangeable parts was possible ecause Whitney used design standards and established anufacturing tolerances.

Today we are sold on this general idea but still have ot applied it fully. Yet wherever design standards are sed, production is speeded and costs are cut. In the llowing, some examples illustrate how design standards nction in, for instance, the production of hydraulic ccessories.

A certain 4-way selector valve had been in operation in airplanes for many months when an Army specification demanded a longer cycling life for the valve. Would a new valve have to be developed, requiring—in the midst of a war—precious weeks or months of designing, testing, modifying, retesting, tooling up, material purchasing, etc., before production began?

The valve in question had been designed to use a square seal. The superior and dependable performance of round or O-ring seals, was already known as a result of experience and steady work on design standards. Due entirely to this knowledge the requisite changes could be made with a minimum of trouble and time.

First, since the bore of the cylinder was known, it was possible to find from a carefully compiled reference table what the correct seal or packing size and its groove dimensions should be. It was not merely a question of substituting a round seal for a square seal, for the round seal required a wider and shallower groove than

Fig. 1—Minimum diametric interference for AN6227 O-ring packings, for both internal and external seals

had been used before. This groove change, in turn, necessitated new pistons. But all the knowledge needed for these substitutions was available. The valve body itself was retained unchanged. The minor changes that were made increased the life of this 4-way valve from about 9000 to 43,000 cycles.

The following tabulation shows how such information may be organized. It is a portion of the specifications covering gland dimensions for AN6227 O-ring seals.

	External Seal			Internal Seal		
	Bore Dia. (in.)	Piston Dia. (in.)	Groove Dia. (in.)	Rod Dia. (in.)	Bore Dia. (in.)	Groove Dia. (in.)
1	0.251 0.249	0.247 0.245	0.139 0.137	0.122 0.120	0.126 0.124	0.234 0.232
2	0.282 0.280	0.278 0.276	0.170 0.168	0.153 0.151	0.157 0.155	0.265 0.263
3	0.313 0.311	0.309 0.307	0.201 0.199	0.184 0.182	0.188 0.186	0.296 0.294
4	0.344 0.342	0.340 0.338	0.232 0.230	0.215 0.213	0.219 0.217	0.327 0.325
5	0.376 0.374	0.372 0.370	0.264 0.262	0.247 0.245	0.251 0.249	0.359 0.357

Each dash number requires its own bore, piston and groove diameter. The groove width is found by reference to another table. AN6227-1 to -7, for instance, all take the same groove width.

If, however, the bore dimension is an odd size and is not found within these prepared tables, the seal information needed is found in other tables and graphs. One graph, for example, shows distortion values. As an O-ring seal is extended or stretched over a rod, its cross section changes in shape from circular to oval. Thus when choosing the correct seal for odd-size bores, the seal's distortion must be known.

In such cases of nonstandard installations, one must also ascertain the minimum diametric interference which will allow the O-ring to seal satisfactorily. The graph which gives this is shown in *Fig.* 1.

Supposing the O-ring which should be used is an external seal No. AN6227-33. From *Fig.* 1 the minimum diametric interference is 0.028-in. This interference is next guaranteed by making the seal groove a certain depth determined from another chart or a formula.

Advantages of standardization are secured in each case by a special study of the unit involved. For seal plugs, for instance, a thorough study was made of the relative merits of the screw plug, the screw cap and the reta or snap ring. Due to economy of manufacture and e of installation, the snap ring was recommended for wherever possible.

Next, its limitations were carefully set down in Design Standards Manual. For instance, snap ri should not be used:

- Where the body is machined from sand-cast aluminum alloy and the system pressure is over 1000 psi
- Where the body is machined from nonferrous metals and the system pressure is over 1500 psi
- Where the body is machined from nonferrous metals and the snap ring would be subjected to frequent removal.

With conditions of use thus set forth as carefully possible, a chart was drawn up like the one for O-rin With a nominal ⅜-in. bore, for instance, the chart dicates that if an internal type N.A.S. 50-37 snap r is used, the other dimensions should be as follows:

Snap-Ring Dia. (in.)	Snap-Ring Width (in.)	Groove Dia. (in.)	Groove Width (in.)	Bore (Actual) (in.)	Clearance of Ring in Place (in.)	Tolerance on Ring Concentricity (in.)
0.414	0.0265	0.409	0.031	0.378	0.19	0.002
0.409	0.0235	0.404	0.028	0.374	...	...

and so on. The correct dimensions for external type sn rings are listed in a similar table.

Such tables often are useful when expressed as grap Thus in employing O-rings as gaskets, a line represe the relation between working pressures and the maxim clearances permissible between body and end seal. F 2 shows that where the working pressure is 1750 p the maximum clearance must not be more than 0.008-

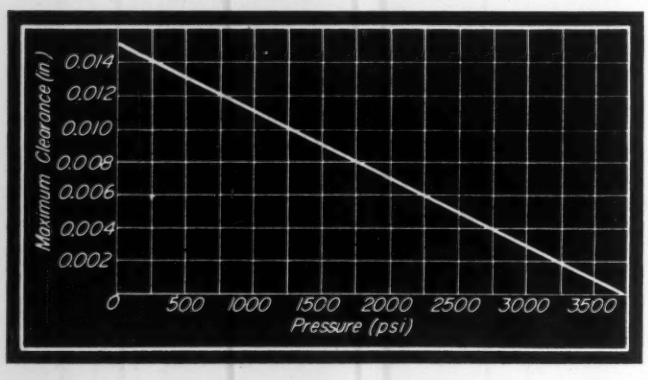
Design standards are useful for countless other ite as, for instance, threads. Though in a given case it often permissible to use any one of several threa analysis usually prescribes a first, second or third choi

Modification of the design of a hydraulic cylinder w serve to illustrate the recognized advantages of utiliz standards. As the development engineer makes his rou layout, he uses standard specifications. These will be help to the draftsman in making the detail layout. H need not be instructed point by point as to the pist diameter, groove diameter, type of seal, etc. Inste the draftsman, be he novice or seasoned, finds what h needs to know in the Design Standards Manual.

After the first model constructed from the detail layo is successfully tested, the production drawing is mad The shop engineer in his turn is happy to see standa parts specified, for this enables him to use standa manufacturing methods with which he is already famili In preference to building a new jig, one already set u may be used. As for tool engineering, supposing th groove width for an O-ring has been standardized, th means that instead of making a new forming tool, standard one may be utilized. Also, the time study d partment knows more than it otherwise would about ho long the various processes of manufacture will take, a the estimating department is already familiar with th unit costs involved.

Such savings all along the line coalesce into one b saving that would not be possible without the help standards.

Fig. 2—Relation between maximum clearance and permissible pressure for O-ring gasket seals



How To Apply Control Transformers

By D. K. Frost

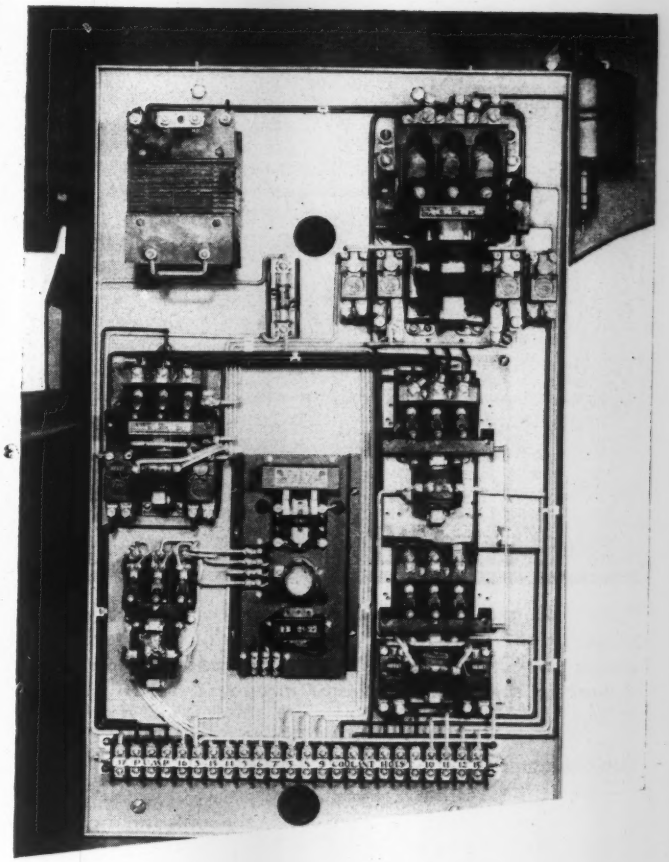
Electrical Engineer
Mattison Machine Works

USE of insulated, reduced-voltage transformers for control circuits has expanded rapidly. This is only natural because, when once employed, the convenience and safety features of low-voltage control become obvious. It is important, however, to understand the purpose and limitations of such devices in order to avoid misapplications and costly errors. The purpose of this article, therefore, is to point out the steps which should be taken so that full benefit of the advantages may be obtained and the application safeguarded.

Referring to the panels shown in *Fig.* 1, it will be noticed that the control transformer has link connections at the top so that the primary or plant voltage may be 220 or 440 volts at either 50 or 60 cycles with the secondary 110 volts. Actually such control transformers are rated 230/460 volts primary and 115 volts secondary; however, this indicates a ratio of 2:1 or 4:1 respectively between primary and secondary. This question of ratio will be covered later in the article.

In making up panels the magnetic switches should be of sufficient size for the horsepower ratings of the various motors regardless of whether they are 220 or 440 volts, especially since all modern motors have nine leads making them readily reconnectible at the terminal boxes for operation at either voltage.

Granting therefore that the panel can be used safely on either 220 or 440 volts, a com-



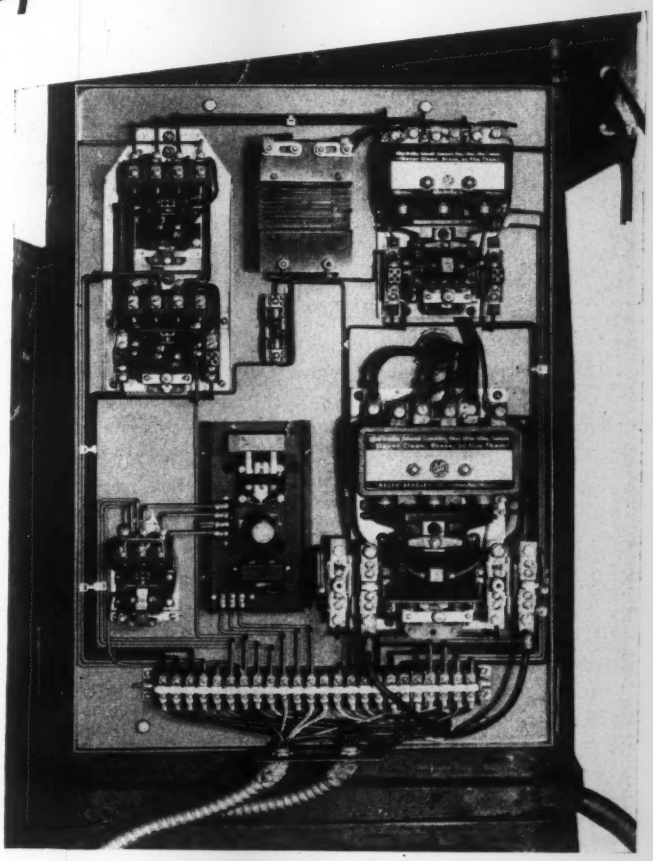


Fig. 1 — Control panels for either 220 or 440-volt supply. Link connections on primary leads of the transformer are changed for either voltage. In the upper view connection is for 440 volts while in the lower panel it is for 220 volts

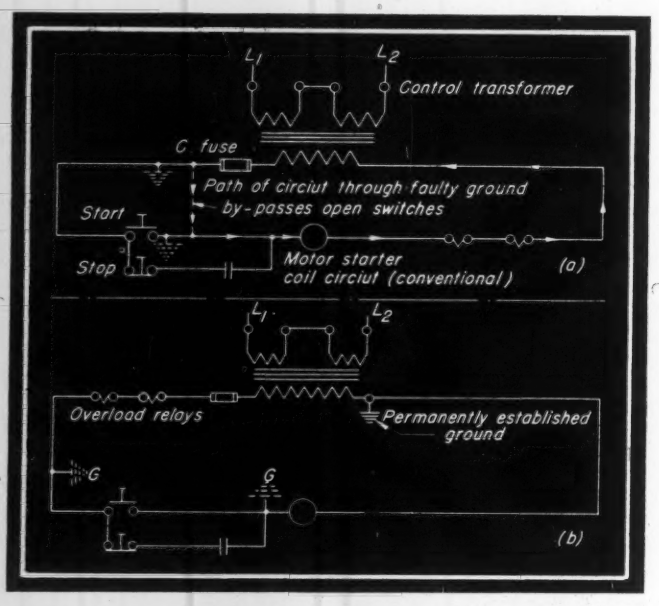


Fig. 2—Grounded control circuit shown at (b) *with possible ground faults indicated in the diagram at* G. *These either should not affect circuit operation or should blow a protecting fuse. Conventional circuit is shown at* (a)

plete machine can be changed over in an hour from operation on either voltage. Because the control circuit for the coils always remains at 110 volts, the only changes necessary consist of reconnecting the motors at the terminal boxes, reconnecting the taps at the transformer primary and changing the overload heater elements on the individual switches. Since the 110-volt control circuit has either fuses or circuit breakers on the secondary side, no change is necessary in that connection.

Limits Power to Transformer Capacity

Another important consideration is the fact that the power behind a short circuit in the control wiring is limited to the secondary short-circuit capacity of a small transformer, usually only 300 to 750 watts capacity. On the other hand, the damage caused by a short circuit without a control transformer in the circuit ahead of the magnetic-switch coils and overload-relay contact points, etc., and with all the power of the shop circuit behind it, can be a measurable amount and might even be a fire hazard.

After inspecting panels where shorts have occurred in the control circuits, especially on line voltages of 440 and 550 volts, the writer is convinced that for this reason alone the use of moderate-power, low-voltage control transformers is not only good practice from the maintenance angle, but also proves to be worth while in reducing inventory expense and increasing availability for quicker turn over of machines from a sales viewpoint. Machines for either voltage, 220 or 440, are available immediately and this can be extended even to 50-cycle machines as explained later.

In regard to the standard 110-volt control circuit, this voltage was selected for various reasons. As the number of machine functions increases so do the number of control contacts in series, and as electrical impedance or resistance is introduced into the circuit it becomes apparent that lower voltages do not have punch enough to operate the devices through these high impedance paths can by adverse conditions such as nonconductive foreign terial between the contacts.

Other complications with reduced voltages in the or of 32-24 or even 12 volts depend on the fact that the perage in the circuit must increase in direct proportion the decrease in voltage for the same amount of power. major part of the power in control circuits is required actuate solenoid coils, whether in contactors, relays other devices. In general lower voltage coils requ heavy wire of fewer turns and higher voltage coils requ small wire of many turns for the same power. Thus voltages are reduced below 110 volts, the coils in stan ard contactors must be made special. On the other ha 110-volt coils are standard stock items in all sizes and all frequencies.

Lower Voltages Affect Contacts Adversely

Limit switches and pushbuttons are adversely affect by the reduced voltage with its increased amperage. Co tact sizes may need to be increased to avoid overheati by the higher currents.

Taking these and other conditions into considerati the proposed revision of the machine tool code, for stance, specifies for low-voltage control circuits:

> The control voltage shall be 110 volts obtained from a transformer with an isolated secondary winding, and the control circuit shall be protected by fuse or equivalent overcurrent protective device placed in the transformer secondary circuit (approximately 95-volt 50-cycle control circuits may be used where 60-cycle coils are used for both 50 and 60-cycle devices).
>
> Recommended Practice: It is recommended that 110-volt reduced-voltage control be used on all machine tools as follows:
>
> (a) All operating coils of magnetic devices should be connected to one side of the control circuit with provision for purchaser's grounding of that side of the line at the control circuit transformer. All contacts should be connected to the other side of the line except as follows: Overload-relay contacts in the line having provision for grounding, if the conductors between such contacts and the coils of magnetic devices do not extend beyond the control enclosure.
>
> (b) The wiring diagram should show the location of the grounding connection with the notation: "To be grounded by purchaser if conditions permit".
>
> 100 volt-ampre additional transformer capacity, or a separate transformer, shall be provided on machines requiring over 2 horsepower, for a 110-volt machine light. Transformers shall have primary winding for dual 220/440 volts unless otherwise specified.

There are some points of interest in the above spe fications and it should prove worthwhile to discuss th in detail and also to make some comments on what shou be taken into consideration in applying these transform correctly.

Grounding of the control transformer in the second has not been tried to any great extent. If one side of t control circuit is grounded, an accidental ground on so

art of the line circuit might produce undesirable relay or ntactor action. That can only be determined over a eriod of time. It is known from experience that con-actors might come in when they should not due to rounds in the control circuit even when the control cir-uit is fused, but not grounded. Certainly, therefore, we uld not be any worse off by trying the grounded circuit s respects erratic operation due to grounds. This connec-on is illustrated in *Fig.* 2. An accidental ground at *G* if low enough resistance should blow the protecting fuse. very high resistance ground probably would not blow e fuse and certainly would not excite the coil.

Arguments against grounding run somewhat along these nes:

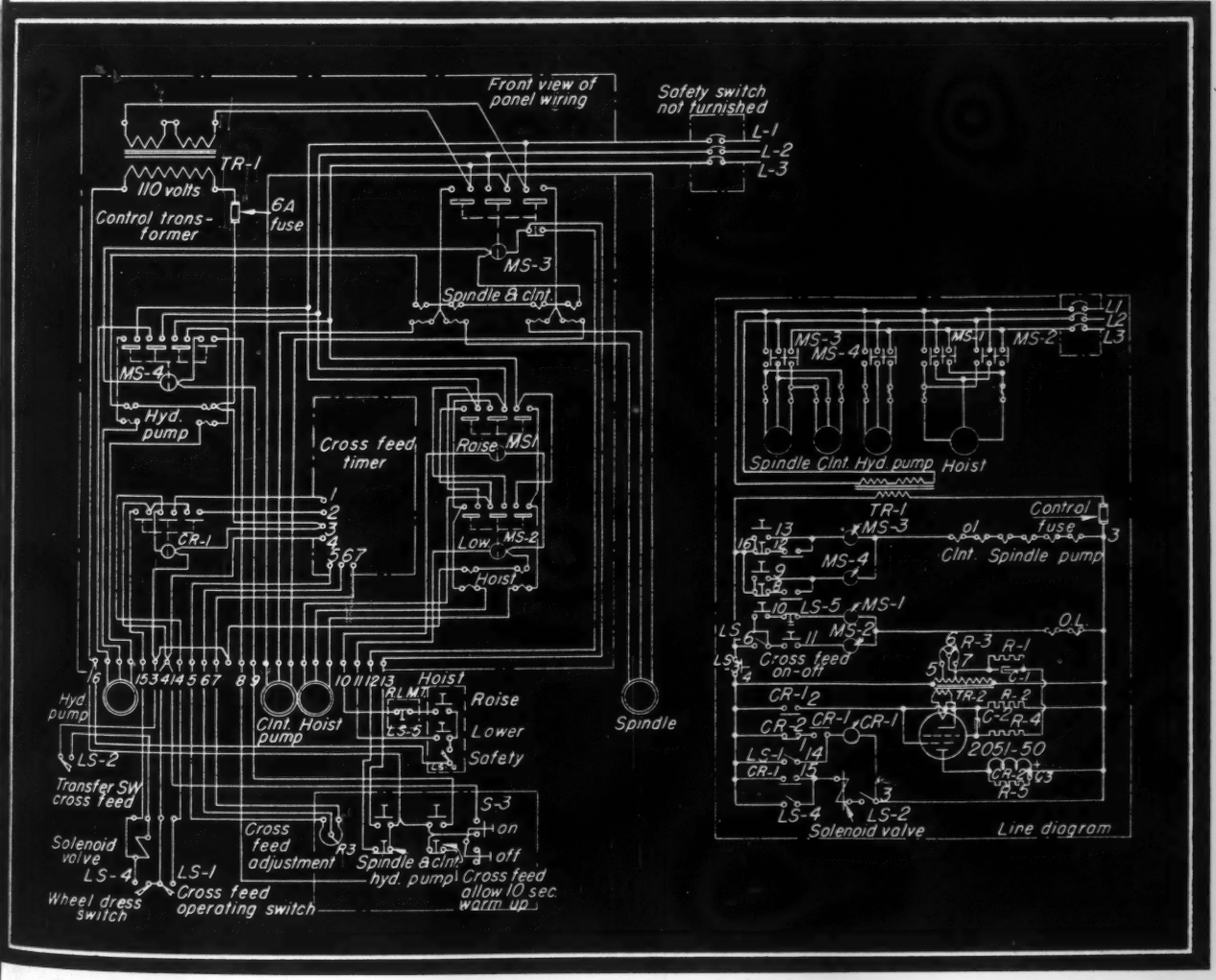
FIRST: It will not permit using a fairly well agreed pon standard method of connecting starters where the verload relay contacts are interposed between the operat-g coil and what normally would be the grounded line. pparently, this will eventually become a NEMA standard nnection scheme. This argument is in reality no argu-ent as far as machine tool standards are concerned be-use this proposed NEMA standard applies only to indi-dual starters receiving control voltage from the main ne. It would, however, block further progress to include is type of connection for low-voltage control circuits. ost multistarter panels follow the recommended practice f connecting one side of all coils to one leg of the trans-former, using the hot side for all control-contact connections as shown in the wiring diagram of *Fig.* 3. That seems to be the common sense way of doing it, because then only one polarity is present on all pushbutton, overload and relay contacts, the hazard of direct short circuits across contacts is avoided.

SECOND: Where one leg of a three-phase system is grounded, trouble might develop through grounding of the isolated secondary of the control circuit transformers if the circuits were not phased out properly. This is the most potent argument against grounding.

Also in the 3-phase, 4-wire circuits and 2-phase, 4-wire and 5-wire circuits the neutral is always grounded and, unless the secondary was phased out correctly, might lead to erratic operation. These are more or less special cases but certainly are worthy of consideration.

Regarding selection of the proper capacity of control transformers a condition exists which certainly needs further study and clarification. Referring to *Fig.* 4 the voltage drop under load is in reality the limiting factor in determining the proper rating for a control transformer. Taking a 500-volt-ampere control transformer as an example and assuming a constant-voltage supply to the pri-

Fig. 3—Wiring diagram for surface grinder follows the recommended practice of connecting all coils to one leg of the transformer. The hot side is used for contacts



mary, the terminal voltage of a 60-cycle 500-volt-ampere control transformer will drop approximately 10 to 11 per cent for a 400 per cent load of 30 per cent power factor. On a terminal basis this same transformer will carry ten times normal load for 20 to 25 seconds without overheating. Usually, therefore, this type of transformer should be applied for voltage regulation rather than on a thermal basis. If overload conditions occur often, say 10 or 15 times per minute, then it may be necessary to determine the equivalent root-mean-square load for alternate cycles of overload and light load.

The average switch-coil inrush current is at a low power factor and, on a control transformer, the reactance is so low that lower power factor current will result in regulation at least as good as a unity power-factor load. The short circuit current of a normal reactance transformer will be approximately 28 times normal full-load current. The short-circuit current from a 500-volt ampere transformer, therefore, might be as much as 110 to 120 amperes peak but this is far less than the short-circuit current from a main power line.

Short Circuit Is Independent of Load

Ordinarily the size of the load current is determined by the work that is being done and bears little relation to the proportions of the system supplying the load. However, the magnitude of short-circuit current is practically independent of the load, but is directly related to the size or capacity of the power source. The larger the capacity of the apparatus which supplies power to the load, the greater the short-circuit current will be. When the short-

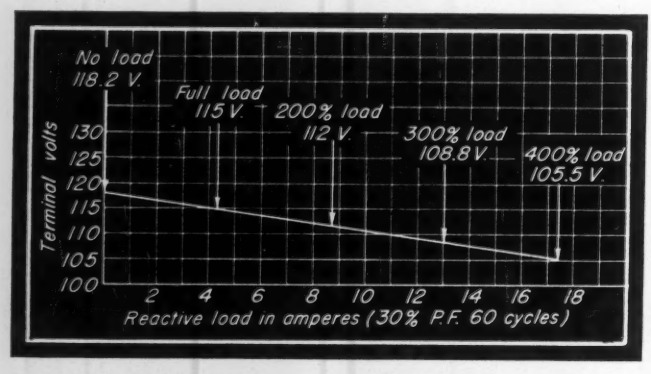


Fig. 4—Regulation curve for control transformer showing voltage drop for various loads

circuit current delivered by the system is in excess of the interrupting capacity rating of the short-circuit protective device (i.e., the breaker or fuse), this protective device may not open the circuit successfully and dangerous as well as destructive consequences may follow.

Fuses must be large enough to carry the normal short-time overload presented by the control devices. Usually it is necessary to over-fuse in order to maintain control circuit continuity during the inrush conditions. If the fuse has the same thermal characteristics as the transformer it will be possible to afford full protection to the transformer. A 10 or 15-ampere fuse on a 500-volt-ampere transformer with a full-load current of 4.35 amperes should be safe.

Though the Automotive Standard allows use of a control transformer with 100 volt-ampre additional capa to furnish current for a machine light in addition to requ ments of the control circuit, the writer believes that such specifications if followed would only lead to trou Certainly the control circuit is too important a part of machine cycling to have its proper functioning jeopardi by adding an unknown quantity of lighting load. If outlet is provided for 110 volts, 60 cycles and this let is connected to the control circuit transformer wha to prevent shop men from plugging in an electric dril tapping tool etc., also of unknown wattage capacity? in time would put too much load on the control tra former, thereby endangering the control circuit continu

Instead, an additional transformer may be included the control panel, such transformer to provide for light service up to 500 watts. This type would also be suita for electric drills and, being separate from the con circuit, if overloaded would not be any liability to functioning of the machine.

With respect to the ratio of voltage reduction, it is p sible to purchase control transformers rated at both and 50 cycles. With such transformers it is feasible take care of 50 cycle jobs as follows:

The normal ratio for instance of a control transfor is 460-volt primary and 115-volt secondary, a ratio of This also means that with 440 volts on the primary secondary will be 110 volts. Now if 60-cycle 110- coils are used they will prove suitable because as long the voltage and frequency change in proportion, tha within reasonable limits, the coils will operate in a nor manner. In other words 95 volts at 50 cycles produces proximately the same current in the coil as 110 volts cycles. That is what is meant by the statement in specifications that approximately 95-volt, 50-cycle con circuit may be used where 60-cycle coils are installed both 50 and 60-cycle devices. Control transformers al considerable leeway in utilizing standard equipment take care of special cycles and voltages, all in a perfec legitimate manner.

Separate Transformers for Auxiliaries Is Best

Control transformers are so handy for lighting and sm tool service that a far-sighted designer will do either of two things. Make the capacity of the control tra former large enough to take care of all these contingenc or specify a separate transformer for lighting and sm tool use so as not to endanger the functioning of the co trol circuit itself. In general it has been found that second method of having a separate transformer for m chine lighting is the safest and best practice to follow.

Known accessory loads of small wattages, howev may be included in the control circuit without endang ing its functioning. For instance, we wanted to appl small lubricating pump motor for a main spindle bearin The motor finally used was a 1/40-horsepower, 1800-r motor. To wind such motors for 3-phase at 440 or 5 volts becomes an almost prohibitive application, but th can be wound readily for 110-volt 60-cycle single-ph power. As the total power consumed by this motor only 30 to 40 watts, it could be operated from the co

(*Concluded on Page* 180)

Interpreting Surface Roughness Readings

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IT HAS become a well-established practice in this country to specify the roughness of a surface in terms of a special kind of average distance, which is the root-mean-square deviation of the surface irregularities from the mean surface. This distance is shown in *Fig.* 1, which represents the magnified profile curve of an idealized surface. The roughness can be read directly by the profilometer, or it can be calculated from the graphical record made by the Brush surface analyzer.

The question arises from time to time as to the physical significance of such a reading. In other words, how far below the peaks are the deepest valleys for an ordinary surface whose rms roughness is known? This question has always been of interest because one can visualize the peak-to-valley distance in terms of the type of reading obtainable with a micrometer, whereas it is extremely difficult to visualize an rms value in terms of the details of the surface profile.

It is the purpose of this article to show how roughness measurements can be converted to linear microinches that can be visualized readily and handled in the same manner as any other linear dimension.

As the subject of surface finish is developing, attention is being paid to waviness, which comprises irregularities more widely spaced than those making roughness, the limit between the two having been arbitrarily set at 0.040-in. The two types of surface irregularities (1)* are depicted schematically in Fig. 2. Since waviness is expressed always in terms of total height, any worthwhile comparison of the waviness and the roughness of a surface requires that both be expressed in the same type of units. Here again it is found desirable to convert the rms roughness (h_{rms}) to the peak-to-valley roughness (h_{max}).

Such a conversion must be made empirically for distinct reasons. In the first place, every surface contains a considerable proportion of roughness irregularities smaller in magnitude than the largest ones. All the roughness irregularities contribute to the rms value, and therefore the rms value is necessarily smaller than if it were calculated on the basis of the larger irregularities alone. Thus the ratio of (h_{max}) to (h_{rms}) depends on the detailed characteristics of the surface. Furthermore, an rms value of the roughness obtained by a tracer-type instrument is not that for the roughness profile itself but rather for the profile as interpreted by the instrument. The tracer point and the electrical and mechanical characteristics of the instrument enter into the interpretation. The distinction between the actual profile and the interpreted version is particularly important when the roughness irregularities are such that their bottoms cannot be reached by the tracer point, whose radius of curvature at the spherical tip is 500 microinches (0.0005-in.) in both the profilometer and the Brush surface analyzer.

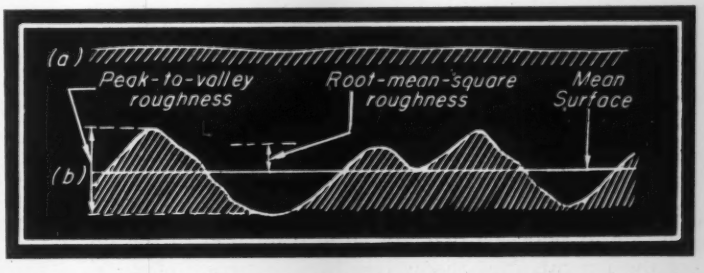
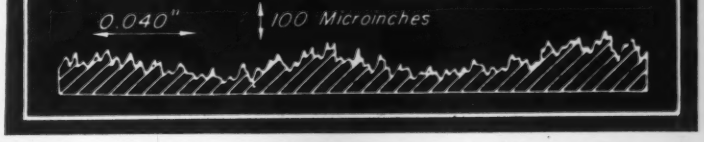


Fig. 1—Sections illustrating a typical surface. True profile (a) is magnified equally in horizontal and vertical directions, exaggerated appearance of same section (b) is result of further magnification of 25 times in vertical direction only

Fig. 2—Section of a surface showing both roughness and waviness irregularities. Roughness, consisting of fine irregularities, is superimposed on waviness which comprises the gradual curvature with wave length greater than 0.040-in.



Some information on the quantity h_{max}/h_{rms} has appeared in the literature. For a simple sine wave, this is of course equal to $2\sqrt{2}$ or 2.8. For profile records of actual surfaces, however, the ratio is likely to be from 3 to 5, according to Abbott, Bousky, and Williamson (2). Much higher ratios than those of Abbott were found by Way (3, 4) whose results indicate that the ratio increases from 3 for extremely rough surfaces to about 10 for

*Abstract of a paper presented at the recent annual meeting of the American Society of Mechanical Engineers in New York.
Numbers in parentheses refer to references at end of article.

commercial finishes and to as high as 25 or 30 for finely ground surfaces.

A third set of ratios can be obtained from Nelson's work on taper sections of steel surfaces prepared by various abrasive operations (5). A taper section is one taken at a small angle to the surface so that the surface irregularities are magnified much more in depth than in width. An optical magnification of 100 diameters, superimposed on a vertical magnification of 25 due to taper sectioning, has been found convenient, this combination giving a horizontal magnification of 100 and a vertical one of 2500.

A photomicrograph of such a section is capable of furnishing the most accurate picture of the true depths of the surface irregularities, and the present work is based upon a detailed examination of Nelson's taper sections, of which only a few were published. The surfaces in question were all finished by various abrasive methods the specimens being SAE 6150 steel hardened and tempered to approximately rockwell C42. Both cylindrical and flat specimens were used. The profilometer readings for the cylindrical specimens were taken along the axial direction, the highest values being obtained in this manner for the reason that the lay of the surface in those cases in which it was unidirectional was perpendicular to the axial direction. The flat specimens were measured in analogous manner relative to the lay.

Visualizing Two Kinds of Roughness

Careful examination of the taper sections revealed that most of the surfaces could best be visualized in terms of two sorts of peak-to-valley roughness. One of these, the roughness that occurs more or less uniformly over the whole surface, we are designating as "predominant peak" roughness. The other, here termed "deepest maximum" roughness, comprises the deepest irregularities occurring at intervals that are large compared to the width of the irregularities themselves but, occurring closer than 0.040-in., are still too close together and too numerous to be disregarded as flaws.

For some surfaces the predominant peak roughness and the deepest maximum roughness are the same. Usually, however, there are deep scratches occurring often enough to be classified as roughness and not as waviness or flaws, and yet not often enough to represent a true base line for the surface irregularities themselves.

Predominant peak roughness is considered significant because the general frictional behavior of an ordinary abrasive-finished surface in original contact with an is most likely to be determined by the roughness in larities present everywhere rather than by the widely arated deep irregularities constituting deepest maxi roughness. There is little reason to expect that an crease in the depth of the deepest irregularities wil fect the contact behavior if the predominant peak ro ness remains unchanged.

A comparison of the ratios h_{max}/h_{rms} for the va types of surfaces appears in the accompanying table. first glance, it may appear that the range of values broad for a given type of finish that calculations inv ing the average ratio listed in the table are not li to be of practical use. However, even a possible e of one-third is not too large when it is considered in shop practice the classes of roughness progress factors of 2.

To illustrate how the average ratios can be appl it is assumed that the profilometer reading is known a given type of surface. Multiplying this reading by corresponding average ratio in the predominant-p roughness column gives the roughness in terms of predominant peak-to-valley height, a distance that is to visualize and one that is well suited for compari of roughness and waviness. The occasional deep ir larities, if needed, are obtained similarly by the use of average ratio in the deepest-maximum-roughness colu

The converse problem, that of establishing a likely v of the profilometer reading if h_{max} is given, requir knowledge of whether or not the deepest maximum regularities were excluded from consideration when was established. If they were excluded, as is likely be the case, the ratio for predominant peak rough should be used, but if h_{max} is based upon the most nounced irregularities, the ratio for deepest maxi roughness should be used. In all these examples, the gree of uncertainty in the calculated quantity can be tained by substituting the extreme values for the ave value given in the table.

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Comparison of Ratios for Various Types of Finish

Type o finish	Cylindrical surfaces				Flat surfaecs			
	"Predominant peak"		"Deepest maximum"		"Predominant peak"		"Deepest maximu	
	Average h_{max}/h_{rms}	Range of h_{max}/h_{rms}	Average h_{max}/h_{rms}	Range of h_{max}/h_{rms}	Average h_{max}/h_{rms}	Range of h_{max}/h_{rms}	Average h_{max}/h_{rms}	Range $h_{max}/$
Ground	4½	3½– 5	8½	6½–10	7	5 – 8	11	7 –1
Hyprolapped	6½	5½– 7½	13	13 –14	6	5½– 6½	15	9½ –2
Sandpapered	7	5½– 9	12	10 –13	7	6½– 7½	17	14 –1
Superfinished	7	5 – 9½	13	11 –16	5½	3½– 7½	10	9 –1
Loose-abrasive-lapped	10	7½–13	19	15 –23	10	5½–13	17	12 –2

MACHINE DESIGN Editorial

Government Aid in Reconversion

ALTHOUGH reconversion has been said to be purely an industrial problem, governmental participation—just as in conversion for war—is one of those things against which there can be no argument. Particularly is this the case in connection with those machine-building companies that have been producing their regular lines of machines throughout the war. These concerns are not faced, as are others, with the task of changing back production lines and entire staffs to something entirely different from their war production—they do not have to "reconvert" in the usual sense of the word. They are, on the other hand, confronted in most cases with the probability of disturbing surpluses existing throughout the nation due to their tremendously increased output during the war years.

One of the most striking examples is the machine tool industry which has produced, since the beginning of 1940, almost as many machines for use in this country as were in operation at that time. By the end of 1945 there will be available for production four times as many machine tools that are less than ten years old as were in use early in 1940.

Whether the country will be able to absorb and utilize the increased potential capacity represented by these relatively new machines is questionable, though recent surveys of machine tool users indicate that a significant demand will be forthcoming, on reconversion, for the more modern types, both new and government owned. It is to take care of the overall surplus that government co-operation is needed, one of the outstanding suggestions along this line being that the government retain as many as 50 per cent of the machine tools to which it holds title at this time.

Not only would such a plan aid in re-establishing the machine tool industry on a peacetime basis, but it would offer the advantage of preparedness and security which should be keynotes of the future. Further, extension of the plan to companies such as road machinery builders and others similarly situated would assure a maximum of employment by these concerns—a factor of vital importance in any consideration of postwar conditions.

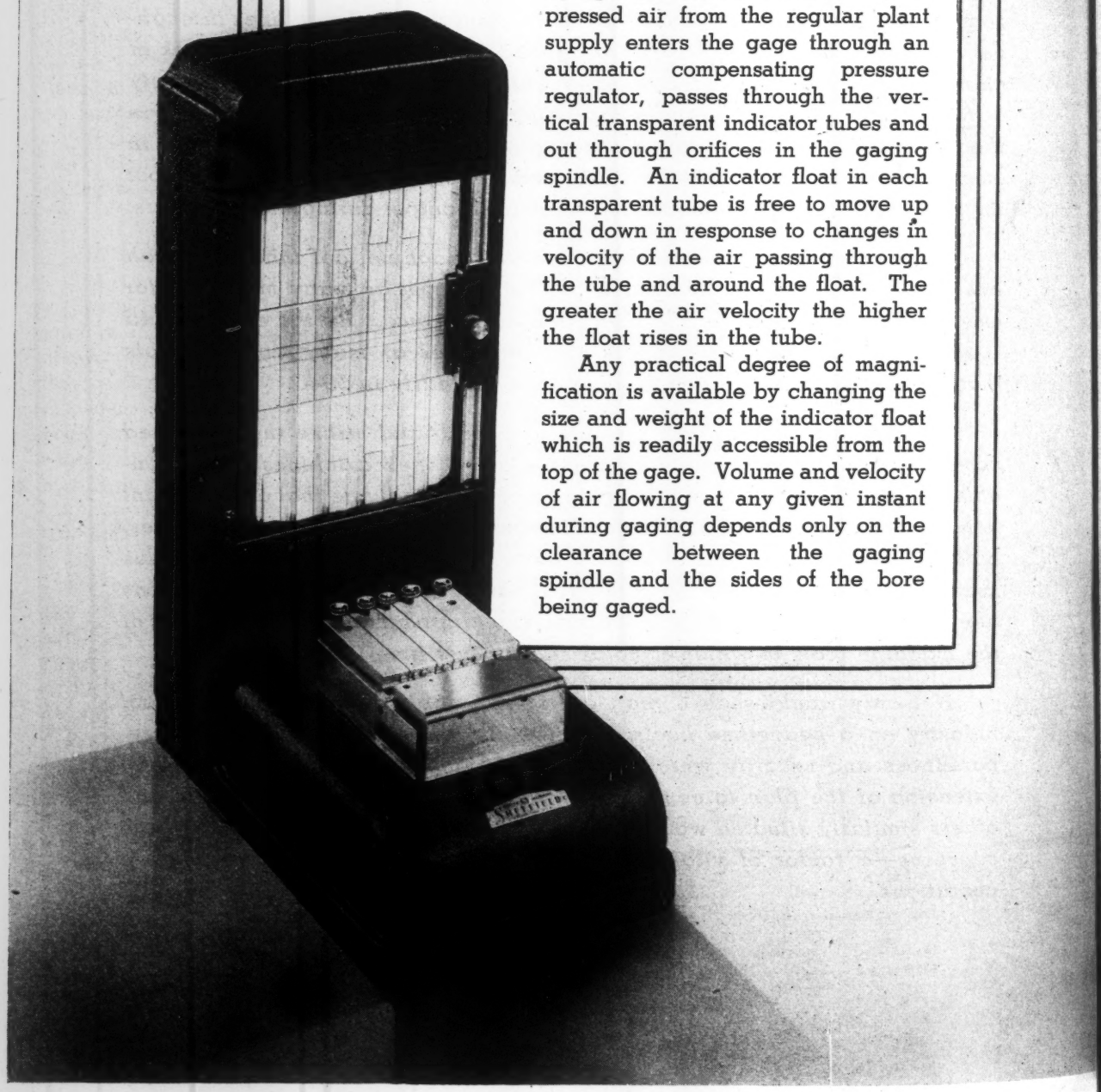
L. E. Jermy

Outstanding Designs

Precision Pneumatic Gage

Capable of checking diameters to plus or minus five millionths of an inch, this new gaging instrument manufactured by The Sheffield corporation employs five transparent indicator tubes. Compressed air from the regular plant supply enters the gage through an automatic compensating pressure regulator, passes through the vertical transparent indicator tubes and out through orifices in the gaging spindle. An indicator float in each transparent tube is free to move up and down in response to changes in velocity of the air passing through the tube and around the float. The greater the air velocity the higher the float rises in the tube.

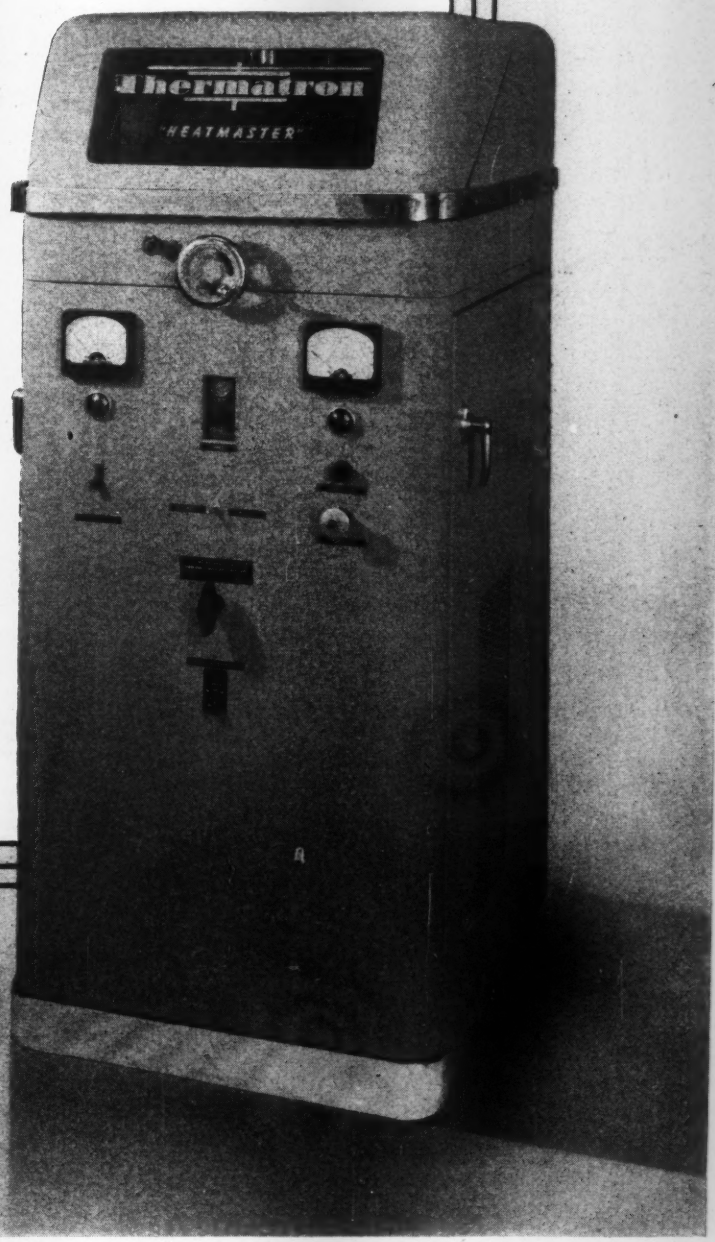
Any practical degree of magnification is available by changing the size and weight of the indicator float which is readily accessible from the top of the gage. Volume and velocity of air flowing at any given instant during gaging depends only on the clearance between the gaging spindle and the sides of the bore being gaged.



Dielectric Heater

Designed for heating dielectric materials such as plastics, wood, and chemical and food products, this machine manufactured by Radio Receptor Co. Inc., consists of a complete high-frequency generator capable of delivering a power output of 5 kw at frequencies of approximately 5, 15 or 30 megacycles. A three-phase, full-wave mercury vapor rectifier is provided for the supply of high-voltage direct current to the oscillator tubes. Cooling is effected by an internal blower system that forces air through the unit, making possible compactness and portability. The machine is provided with either an automatic oven, mounted at the top, or a separate electrode assembly for application of radio frequencies to the product. The 5 kw output is capable of supplying 17,065 Btu per hour to the load.

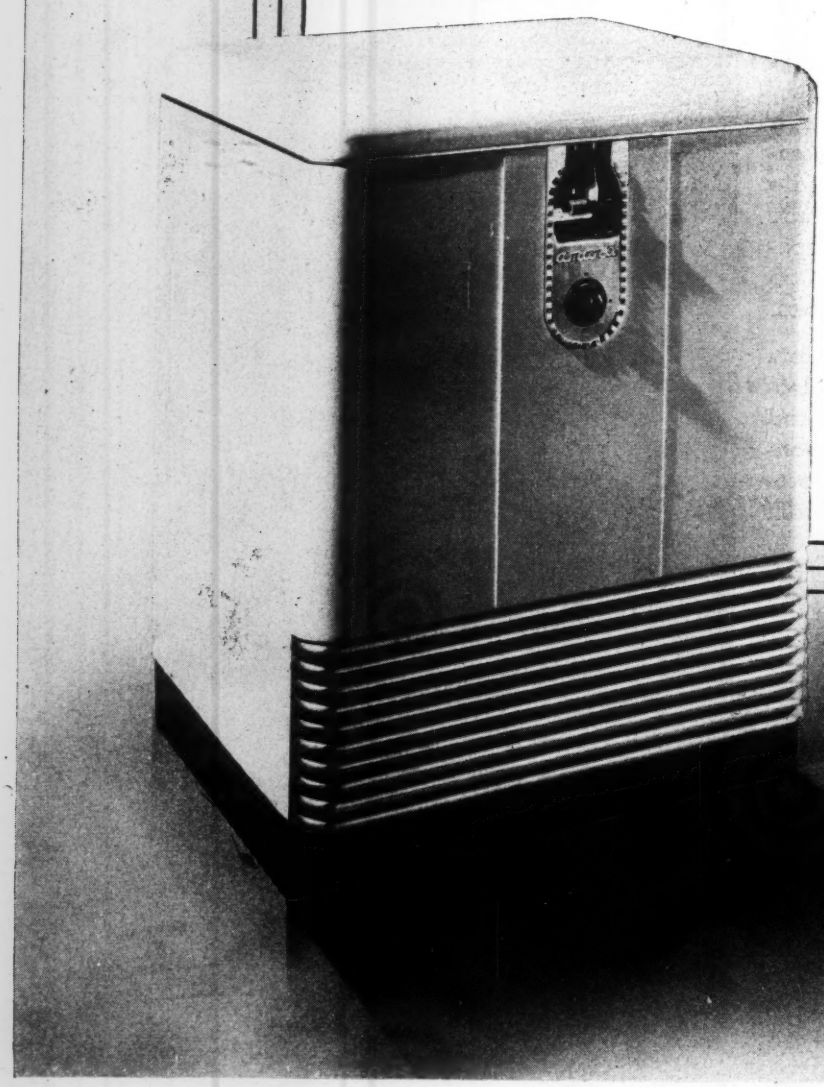
Use of glass-wool filters protects the internal electrical parts from dust and dirt. Protective and control systems insure protection of the equipment and prevent injury to personnel operating the equipment.



Home Freezer

This five-cubic-foot home freezer employs a one-piece stamped and formed aluminum lid and main body of welded sheet steel construction. Designed by Karl Brocken and manufactured by the refrigerator division of the Amana Society, its lid gasket is specially designed to prevent the lid from freezing shut.

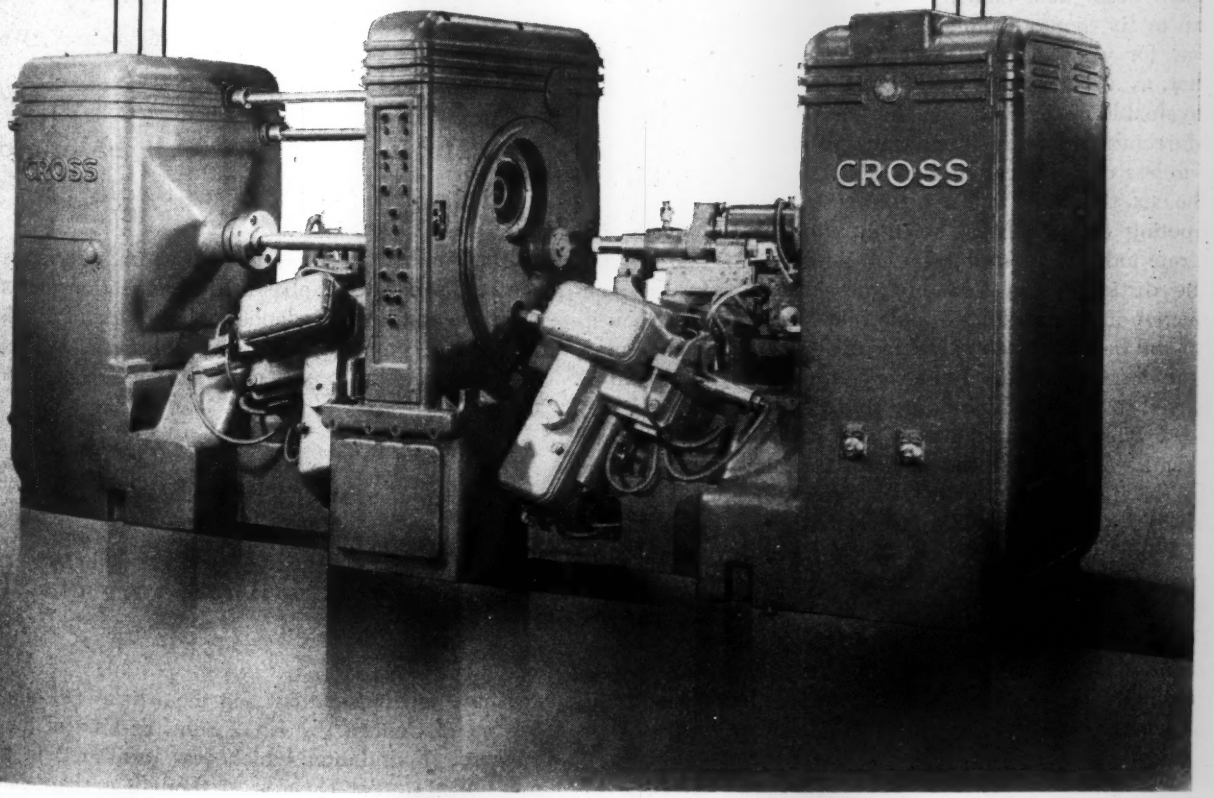
With conventional white employed for the main body, the base is black and recessed to provide ample toe room. Temperature-control knob, mounted just below the lid-locking handle, is of red plastic as is the hand hold of the handle which fits into a recess to prevent it from catching on clothing. Escutcheon plate used has a chrome-plated satin finish. The slightly raised center panel gives a ribbing effect that serves to stiffen the front of the box. Grill at the base is readily removable, permitting access to the compressor through the front of the freezer. Hinges are unexposed, being built-in to the sides of the box. The lid, being counter-balanced, will stay open in any position.



Grinder and Honer

Used for internal grinding and honing of two opposed conical surfaces—four operations that formerly required separate machines and operators—this machine, made by The Cross Co., has an automatic operating cycle controlled by a centralized pushbutton station. Its workhead has three spindles. Each is indexed from the loading station to the grinding station, from there to the honing station and then back to the loading station in successive cycles.

Manual control pushbuttons are provided for individual set-up of the grinding and honing heads. During regular operation, these heads perform all their operations automatically. The grinding heads move into working position with the wheels oscillating, then the wheels are fed for rough grinding, retracted for dressing, fed for finish grinding and retracted to clear the work. The honing heads move the honing tools into the work and feed them against the tapered surfaces with automatic compensation for stone wear. Grinding coolant, flushing fluid and honing compound are contained in separate built-in tanks.



PROFESSIONAL VIEWPOINTS

MACHINE DESIGN welcomes comments from readers on subjects of interest to designers. Payment will be made for letters and comments published

". . . opinion was sound"

To the Editor:

G. V. Woodling's argument in your February issue that "Group Invention Must Be Upheld" may be sound, but it would be more apparently so had he not cited the Supreme Court's opinion in the Marconi cases. Yet it is that very citation which evokes the approval of Dr. Elek Benedek in your April issue. As a matter of fact, this opinion of the Supreme Court on June 21, 1943, was as sound as any opinion ever handed down by any court. I have personal knowledge of the facts and can testify to his, nevertheless it was quite irrelevant to the upholding of group invention.

As an example of popular misunderstanding on this subject I quote Mr. Woodling's own statement that "Prior to Marconi's discovery, the greatest scientists and electrical wizards of the day were unable to send wireless messages much more than eighty miles. Marconi lengthened the arc to six thousand miles". It is a fact that eighty miles was for years beyond even Marconi's dreams, and half that, as a dependable working distance, would have been invaluable to the British in the Boer War of 1899-02. Yet Marconi's men were there and their attempts to establish wireless communication were abandoned as futile. As to the six thousand miles, I think Mr. Woodling must be quoting one of those "scientifically and technically illiterate judges" referred to by Dr. Benedek, for that is about the distance from Rome to these shores. In this connection it is interesting to note that Marconi's most powerful and beautiful station was located at Coltano near Rome, and despite this the Italian government invited Cyril F. Elwell to build a Poulsen arc station, so urgently did they need wireless communication with America during World War I. This Elwell did, and for so doing was decorated by the Italian government and earned for himself the title of "the man who put the arc in Marconi".

While on this subject, it may be pertinent to state that Marconi's presumed receipt of three S's at Signal Hill, Newfoundland from England in 1901 has never since been repeated or paralleled with similar power and equipment. Moreover, no skilled wireless telegraph operator took part in that experiment and no independent authority affirmed its results.

—ARTHUR H. MORSE
Elmhurst, L. I., N. Y.

To the Editor:

The Marconi case was cited in my article as an exam to illustrate the point that the test for invention should b based upon whether or not the thing invented gives i proved results over the old, and not whether the inven had a flash of genius at the time he made the inventi Essentially, the Supreme Court decision, in holding t broad claims of the Marconi patent invalid, was bas upon the fact that what Marconi created was not the r sult of a flash of genius. Had the Supreme Court bas its decision upon whether or not the Marconi discove constituted an engineering achievement, then the bro claims would no doubt have been held valid. The reas this decision has a bearing upon group invention is that w group invention it is generally found that no one in t group had a flash of genius at the time that the gro made the invention. Therefore, the flash of genius test employed by the Supreme Court in the Marconi case op ates to invalidate invention made by a group.

—GEORGE V. WOODLI

"subject matter well balanced"

To the Editor:

The number of trade and engineering magazines now the field serves to emphasize the tremendous editorial ta of producing a well balanced magazine and in this rega I wish to comment that your February, 1945, issue MACHINE DESIGN represents a fine choice of subject ma ter.

—PETER F. ROSSMANN, *Gen. Mgr. Development Div. Curtiss-Wright Cor*

" . . . cost will not vary greatly"

To the Editor:

I have just finished reading the article "Selecting Drive for Speed Control" by E. L. Schwarz-Kast of the Armo Research Foundation which was published in the Ju issue of MACHINE DESIGN. I thought perhaps some co

ts which came to our minds while reading the article ld be of general interest.

s you may suspect, this has to do with the so-called rd-Leonard or Variable-Voltage System. These are well described by the author, except perhaps from standpoint of cost, economy, maintenance, and space uirements. On Page 172, under "First Cost" we note author says this equipment is higher in cost than the tric resistance methods but no decisive difference as pared with hydraulic and mechanical devices. In our nion the equipment is higher in cost than the ordinary tor with the resistance speed control method, that is, nt fields, etc., if no consideration is given to the cost of direct-current generation equipment and plant distri- ion. If a proper portion of the cost of the direct-current ducing equipment, the distribution and the direct- rent motor starting equipment are added, the cost not vary greatly from the Ward-Leonard system in y cases.

n the case of hydraulic equipment we have found that ch a system consists only of a central pump and several nders, it is generally favorable when compared to the tric. However, if the hydraulic motion is extremely requiring a single long cylinder, or possibly a hydrau- motor, economy very rapidly swings in favor of the trical equipment. In the case of mechanical devices ultitude of items are covered. In some cases electrical ipment does represent a cost saving, while in others oes not.

Under "Electronic Control of D-C Motor" on Page 174 comment is made "instead of the roomy motor-generator set there is only a small space for the transformer and the control panel required." Above 3 hp this does not seem to be right to our minds. As you know, we make both the electronic and the rotating equipment and we find that horsepower for horsepower the space required is about the same.

—Paul W. Arnold
Reliance Electric & Engineering Co.

". . . conducive to easy reading"

To the Editor:

I have read with considerable interest the Engineering Data Sheet, "Improved Methods for Calculating Torsional Vibration" by R. H. Scanlon. The subject has been presented in a manner conducive to easy reading.

However, I believe that the conventional Holzer method is less time-consuming for ordinary internal combustion engine work. Usually, the designer can guess (from experience) or estimate the first and second normal mode frequencies with sufficient accuracy so that only three or perhaps four Holzer calculations are necessary for each frequency. This is especially true for systems having relatively few degrees of freedom.

The iteration method outlined in this article undoubtedly is easier to use for systems with many degrees of freedom and also when several modes are desired.

—Sherman Vannah, *Vibration Engineer*
Aircooled Motors Corp.

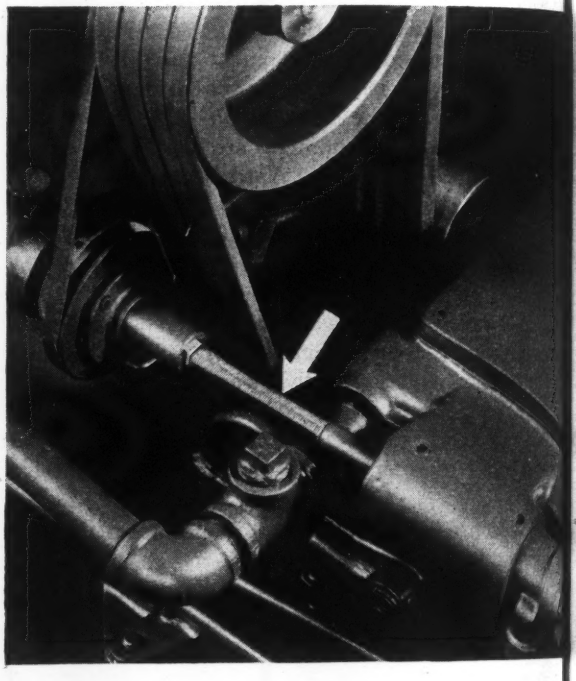
"You and your air-conditioning ideas!"

Applications

of Engineering Parts, Materials and Processe

Coupling for Belted Drive

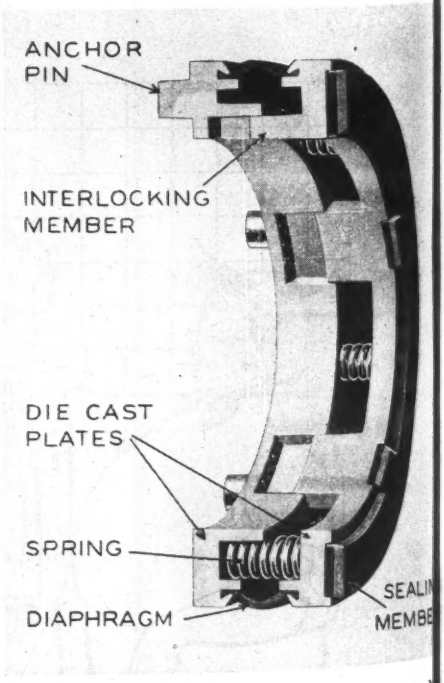
TO PROVIDE ample range of adjustment for belt tension, a flexible shaft coupling is utilized to drive the hydraulic pump for the selector mechanism of the Gisholt turret lathe shown at the right. The belted drive operates this pump through the coupling, delivering a constant supply of oil under 400 pounds pressure. Tension of the V-belt may be adjusted as required without disturbing the arrangement.



Aids Aircraft Design

PHYSICAL qualities and forming characteristics of Haskelite Plastiply facilitates design and assembly of helicopter side panels shown in the R-6 military helicopter, below. The laminated plastic panels feature unusually high strength-weight ratio, good insulating properties, and resistance to oils, acids, alkalis, weathering and fungus. Panels are molded to shape during the curing process assuring satisfactory mass production assembly.

Die-Cast Oil Seal



ZINC alloy die castings are utilized for the two spring-loaded mating parts of the Chicago Rawhide oil seal, right above. Providing the necessary strength and toughness along with good resistance to galvanic corrosion when supplied with a similar metal sealing member, the seals widely used in army tractors, machine washing machines, etc.

Design Formulas for Three-Link Screw Mechanisms

By William H. Rasche

Professor of Mechanism
Virginia Polytechnic Institute

LITTLE is to be found in textbooks concerning three-link screw mechanisms, while the available information is presented in such a manner as to be of little service to the designer. What the designer wants is a mathematical formula that will not only help him to understand the behavior of the device but will also enable him to design it to fulfill the conditions imposed by the application. Such formulas are presented in this Data Sheet.

Three of the four screw mechanisms with which the data sheet deals are of great practical importance to the engineer. The fourth (*Fig.* 4) which has three screw pairs has not, to the author's knowledge, been used hitherto, but it is possible that practical applications of it might result if its characteristics were better known.

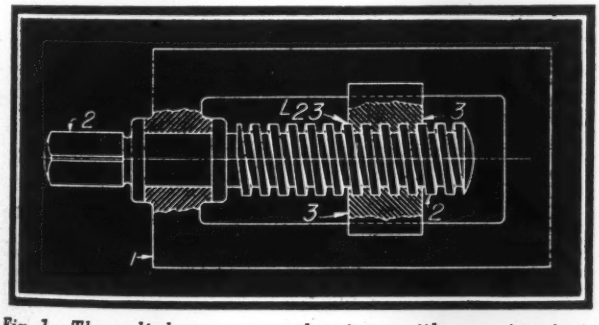


Fig. 1—Three-link screw mechanism with one turning pair (1,2), one sliding pair (1,3), and one screw pair (2,3). For this case the following relations hold: $T_{21}=0;\ N_{31}=0;\ L_{21}=0;\ L_{31}=\infty$

DEFINITION: A three-link screw mechanism is a combination of three links, each of the links being paired to each of the others by a lower (surface contact) pair, and one at least of the pairs being a screw-pair.

CLASSIFICATION: Three-link screw mechanisms are of four kinds:

1. One screw pair, one turning pair and one sliding pair, *Fig.* 1
2. Two screw pairs and one sliding pair, *Fig.* 2
3. Two screw pairs and one turning pair, *Fig.* 3
4. Three screw pairs, *Fig.* 4

CONVENTIONS: The following four conventions are indispensable to the correct use of the formulas:

I. The observer stands on the left of the mechanism and looks at it from left to right

II. The symbol representing the angular displacement or angular velocity of one link relative to a second takes the positive or the negative sign according as the first link rotates relative to the second in a clockwise or counterclockwise sense

III. The symbol representing linear travel or displacement of one link relative to a second takes the positive or the negative sign according as the first link moves relative to the second from left to right or from right to left

IV. The lead of a screw pair takes the positive or the negative sign according as the screw pair is right or lefthand.

BASIC FORMULAS: The following group of formulas, A, B and C, are basic relationships* which apply to the most general case of a mechanism with three screw pairs, *Fig.* 4. For the other three mechanisms, certain terms drop out, as indicated in the captions for *Figs.* 1, 2 and 3. Explanation of the symbols is given in the Nomenclature on Page 148.

Formulas A

$$T_{21}=(N_{21}t)L_{21} \quad \ldots\ldots (1)$$

$$T_{31}=(N_{31}t)L_{31} \quad \ldots\ldots (2)$$

$$T_{23}=(N_{23}t)L_{23} \quad \ldots\ldots (3)$$

Formula B

$$T_{21}+T_{13}+T_{32}=0$$

*Derivations of these basic formulas will be found in a bulletin of the Virginia Polytechnic Institute, Engineering Experiment Station Series No. 58, on "Classification and Kinematic Analysis of 3-link Screw Mechanisms", by the author.

ENGINEERING DATA SHEET

Formula C

$$N_{21}t+N_{13}t+N_{32}t=0$$

DERIVED FORMULAS: The remaining group of formulas, D, E, F, G, H, I, J, and K are derived from the foregoing basic formulas, and apply to the general case of a mechanism with three screw pairs, *Fig.* 4. For the other three mechanisms, certain terms drop out, as indicated in the captions for *Figs.* 1, 2 and 3.

Formulas D

$$\frac{N_{21}t}{N_{31}t}=\frac{L_{23}-L_{31}}{L_{23}-L_{21}} \quad \ldots\ldots (1)$$

$$\frac{N_{12}t}{N_{32}t}=\frac{L_{13}-L_{32}}{L_{13}-L_{12}} \quad \ldots\ldots (2)$$

$$\frac{N_{13}t}{N_{23}t}=\frac{L_{12}-L_{23}}{L_{12}-L_{13}} \quad \ldots\ldots (3)$$

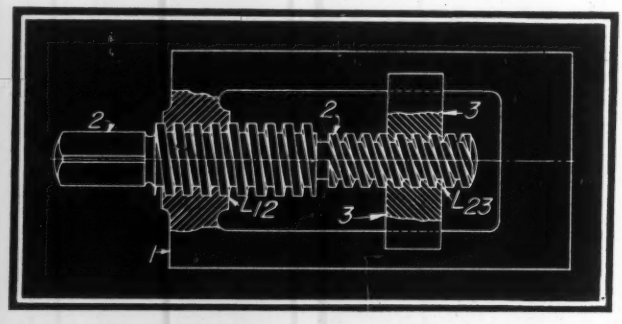


Fig. 2—Three-link screw mechanism with one sliding pair (1,3) and two screw pairs (1,2 and 2,3). For this case the following relations hold: $N_{31}=0$; $L_{31}=\infty$

Formulas E

$$\frac{N_{21}t}{T_{31}}=\frac{L_{23}-L_{31}}{L_{31}(L_{23}-L_{21})} \quad \ldots\ldots (1)$$

$$\frac{T_{21}}{N_{31}t}=\frac{L_{21}(L_{23}-L_{31})}{L_{23}-L_{21}} \quad \ldots\ldots (2)$$

$$\frac{N_{13}t}{T_{32}}=\frac{L_{13}-L_{32}}{L_{32}(L_{13}-L_{12})} \quad \ldots\ldots (3)$$

$$\frac{T_{12}}{N_{32}t}=\frac{L_{12}(L_{13}-L_{32})}{L_{13}-L_{12}} \quad \ldots\ldots (4)$$

$$\frac{N_{13}t}{T_{23}}=\frac{L_{12}-L_{23}}{L_{23}(L_{12}-L_{13})} \quad \ldots\ldots (5)$$

$$\frac{T_{13}}{N_{23}t}=\frac{L_{13}(L_{12}-L_{23})}{L_{12}-L_{13}} \quad \ldots\ldots (6)$$

Formulas F

$$\frac{T_{21}}{T_{31}}=\frac{L_{12}L_{23}-L_{21}L_{31}}{L_{31}L_{23}-L_{21}L_{31}} \quad \ldots\ldots (1)$$

$$\frac{T_{12}}{T_{32}}=\frac{L_{12}L_{13}-L_{12}L_{23}}{L_{23}L_{13}-L_{12}L_{23}} \quad \ldots\ldots (2)$$

$$\frac{T_{13}}{T_{23}}=\frac{L_{13}L_{12}-L_{13}L_{23}}{L_{23}L_{12}-L_{13}L_{23}} \quad \ldots\ldots (3)$$

Formulas G

$$t=\frac{L_{23}-L_{31}}{L_{31}(L_{23}-L_{21})}\,\frac{T_{31}}{N_{21}} \quad \ldots\ldots (1)$$

$$t=\frac{L_{23}-L_{21}}{L_{21}(L_{23}-L_{31})}\,\frac{T_{21}}{N_{31}} \quad \ldots\ldots (2)$$

$$t=\frac{L_{13}-L_{23}}{L_{32}(L_{13}-L_{12})}\,\frac{T_{32}}{N_{12}} \quad \ldots\ldots (3)$$

$$t=\frac{L_{13}-L_{12}}{L_{12}(L_{13}-L_{23})}\,\frac{T_{12}}{N_{32}} \quad \ldots\ldots (4)$$

$$t=\frac{L_{12}-L_{23}}{L_{23}(L_{12}-L_{13})}\,\frac{T_{23}}{N_{13}} \quad \ldots\ldots (5)$$

$$t=\frac{L_{12}-L_{13}}{L_{13}(L_{12}-L_{23})}\,\frac{T_{13}}{N_{23}} \quad \ldots\ldots (6)$$

Nomenclature

$N_{21} = -N_{12}$ = Angular velocity of link 2 relative to link 1, revolutions per minute

$N_{31} = -N_{13}$ = Angular velocity of link 3 relative to link 1, revolutions per minute

$N_{23} = -N_{32}$ = Angular velocity of link 2 relative to link 3, revolutions per minute

$T_{21} = -T_{12}$ = Linear travel or displacement of link 2 relative to link 1, inches

$T_{31} = -T_{13}$ = Linear travel or displacement of link 3 relative to link 1, inches

$T_{23} = -T_{32}$ = Linear travel or displacement of link 2 relative to link 3, inches

$N_{21}t = -N_{12}t$ = Angular displacement, revolutions, of link 2 relative to link 1, where t is in minutes

$N_{31}t = -N_{13}t$ = Angular displacement, revolutions, of link 3 relative to link 1, where t is in minutes

$N_{23}t = -N_{32}t$ = Angular displacement, revolutions, of link 2 relative to link 3, where t is in minutes

$L_{21} = L_{12}$ = Lead of screw pair 21, inches

$L_{31} = L_{13}$ = Lead of screw pair 31, inches

$L_{23} = L_{32}$ = Lead of screw pair 23, inches

Formulas H

$$L_{23}=\frac{(N_{21}t)L_{21}-(N_{31}t)L_{31}}{N_{21}t-N_{31}t} \quad \ldots\ldots(1)$$

$$L_{21}=\frac{(N_{23}t)L_{23}-(N_{31}t)L_{31}}{N_{23}t-N_{31}t} \quad \ldots\ldots(2)$$

$$L_{31}=\frac{(N_{23}t)L_{23}-(N_{21}t)L_{21}}{N_{23}t-N_{21}t} \quad \ldots\ldots(3)$$

Formulas I

$$L_{23}=\frac{T_{21}-T_{31}}{N_{21}t-N_{31}t} \quad \ldots\ldots(1)$$

$$L_{21}=\frac{T_{23}-T_{31}}{N_{23}t-N_{31}t} \quad \ldots\ldots(2)$$

$$L_{31}=\frac{T_{23}-T_{21}}{N_{23}t-N_{21}t} \quad \ldots\ldots(3)$$

Formulas J

$$t=\frac{T_{21}-T_{31}}{L_{23}(N_{21}-N_{31})} \quad \ldots\ldots(1)$$

$$t=\frac{T_{23}-T_{31}}{L_{21}(N_{23}-N_{31})} \quad \ldots\ldots(2)$$

$$t=\frac{T_{23}-T_{21}}{L_{21}(N_{23}-N_{21})} \quad \ldots\ldots(3)$$

Formulas K

$$L_{21}=\frac{T_{31}L_{23}}{T_{31}+(N_{21}t)(L_{23}-L_{21})} \quad \ldots\ldots(1)$$

$$L_{21}=\frac{T_{21}L_{23}}{T_{21}+(N_{31}t)(L_{23}-L_{31})} \quad \ldots\ldots(2)$$

$$L_{23}=\frac{T_{23}L_{21}}{T_{23}+(N_{13}t)(L_{21}-L_{31})} \quad \ldots\ldots(3)$$

$$L_{13}=\frac{T_{13}L_{12}}{T_{13}+(N_{23}t)(L_{12}-L_{23})} \quad \ldots\ldots(4)$$

$$L_{12}=\frac{T_{12}L_{13}}{T_{12}+(N_{32}t)(L_{13}-L_{32})} \quad \ldots\ldots(5)$$

$$L_{32}=\frac{T_{21}L_{13}}{T_{32}+(N_{21}t)(L_{13}-L_{12})} \quad \ldots\ldots(6)$$

PROBLEM SOLUTION: In selecting the formulas to use in a particular problem, the table on Page 151 provides a convenient reference. To give further insight into the use of the formulas and the characteristics of three-link screw mechanisms, numerical examples corresponding to certain of these problems are worked out in the following:

EXAMPLE 7′: For the three-link screw mechanism, *Fig.* 2, given $L_{21}=0.4$-in. RH, $L_{23}=0.75$-in. LH, $(L_{31}=\infty)$, and $T_{31}=6$ in. L to R; required T_{21}, T_{23}, $N_{21}t$, $N_{23}t$, and $N_{31}t$.

1. From Formula F1:

$$T_{21}=\frac{L_{12}L_{23}-L_{12}L_{31}}{L_{31}L_{23}-L_{12}L_{31}}T_{31}=\frac{\dfrac{L_{12}L_{23}}{L_{31}}-L_{12}}{L_{23}-L_{12}}T_{31}$$

$$=\frac{0-0.4}{-0.75-0.4}\times 6=2.087\text{-in. travel, L to R}$$

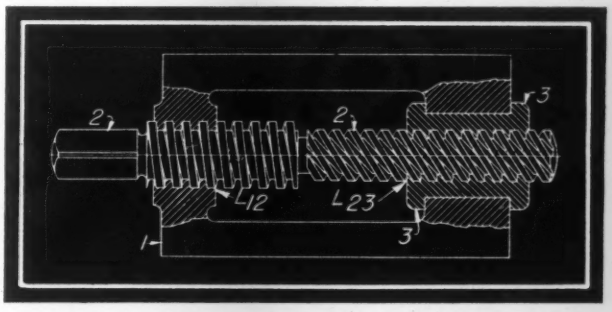


Fig. 3—Three-link screw mechanism with one turning pair (1,3) and two screw pairs (1,2 and 2,3). For this case the following relations hold: $T_{31}=0$; $L_{31}=0$

2. Formula B gives:

$$T_{23}=T_{13}+T_{21}=T_{21}-T_{31}$$

$$=2.087-6=-3.913\text{-in. travel, R to L}$$

3. From Formulas A1, A2, and A3:

$$N_{21}t=\frac{T_{21}}{L_{21}}=\frac{2.087}{0.4}=5.217 \text{ revs, clockwise}$$

$$N_{31}t=\frac{T_{31}}{L_{31}}=\frac{6}{\infty}=0 \text{ (obvious from the figure)}$$

$$N_{23}t=\frac{T_{23}}{L_{23}}=\frac{-3.913}{-0.75}=5.217 \text{ revs, clockwise}$$

EXAMPLE 7″: for the three-link screw mechanism, *Fig.* 2, given $L_{23}=0.75$-in. LH, $(L_{31}=\infty)$, $N_{21}t=30$ revolutions, clockwise, and $T_{31}=6$-in. travel, L to R; required T_{21}, T_{23}, L_{21}, $N_{23}t$, and $N_{31}t$.

1. Since $N_{21}t$ obviously is equal to $N_{23}t$, from Formula A3:

$$T_{23}=(N_{23}t)L_{23}=(N_{21}t)L_{23}$$

$$=30(-0.75)=-22.5\text{-in. travel, R to L}$$

2. It follows from Formula B that

$$T_{21}=T_{31}+T_{23}=6+(-22.5)=-16.5\text{-in. travel, R to L}$$

3. And Formula A1 gives

$$L_{21}=\frac{T_{21}}{N_{21}t}=\frac{-16.5}{30}=-0.55\text{-in. L H}$$

4. Inspection of *Fig.* 2 shows that $N_{31}t=0$. This follows also from equation C since, as already pointed out, $N_{21}t=N_{23}t$.

Alternatively: If only L_{21} is wanted, it can be found more directly from Formula K1 in which, since L_{31} is equal to infinity,

$$T_{31}+(N_{21}t)(L_{23}-L_{21})=0$$

that is,

$$L_{21}=\frac{T_{31}}{N_{21}t}+L_{23}=\frac{6}{30}+(-0.75)$$

$$=0.2-0.75=-0.55\text{-in. L H}$$

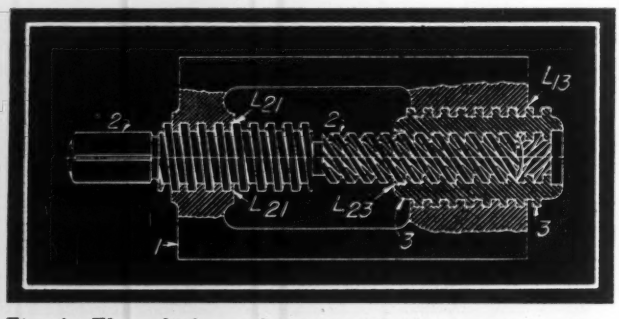


Fig. 4—Three-link mechanism with three screw pairs

EXAMPLE 10′: For the three-link screw mechanism, *Fig.* 3, given $L_{23}=10$ in. RH, $(L_{31}=0)$, $T_{21}=200$-in. travel L to R, and $N_{31}t=-100$ revolutions, counterclockwise; required L_{21}, $N_{21}t$, T_{23}, and $N_{23}t$.

1. From Formula K2

$$L_{21}=\frac{T_{21}L_{23}}{T_{21}+(N_{31}t)(L_{23}-L_{31})}$$

$$=\frac{200\times10}{200+(-100)(10-0)}=-2.5\text{ in. L H}$$

2. From Formula A1,

$$N_{21}t=\frac{T_{21}}{L_{21}}=\frac{200}{-2.5}$$

$$=-80\text{ revs. counterclockwise}$$

3. From Formulas B and A3

$$T_{23}=T_{13}+T_{21}$$

$$=0+200=200\text{ in. travel, L to R}$$

$$N_{23}t=\frac{T_{23}}{L_{23}}=\frac{200}{10}=20\text{ revs, clockwise}$$

EXAMPLE 10″: For the three-link screw mechanism *Fig.* 1 $(L_{21}=0)$, given $L_{23}=0.2$-in. RH, $(L_{31}=\infty)$ $T_{31}=5$-in. travel, L to R; required $N_{21}t$, $N_{23}t$, and T_{32}.

1. Inspection of *Fig.* 1 shows that $N_{21}t=N_{23}t$, and $T_{32}=T_{31}=5$ in.; therefore $T_{23}=-5$-in. travel, R to L.

2. From Formula A3

$$N_{23}t=N_{21}t=\frac{T_{23}}{L_{23}}$$

$$=-\frac{5}{0.2}=-25\text{ revs, counterclockwise}$$

Alternatively:

1. $N_{21}t$ $(=N_{23}t)$ can be found from Formula E1 as follows:

$$N_{21}t=\frac{\frac{L_{23}}{L_{31}}-1}{L_{23}-L_{21}}\,T_{31}$$

$$=\frac{0-1}{0.2-0}\times5=-25\text{ revs, counterclockwise}$$

2. Similarly T_{23} can be found from Formula E4 thus:

$$T_{23}=\frac{L_{23}(L_{13}-L_{12})}{L_{13}-L_{32}}(N_{21}t)=\frac{L_{23}-\frac{L_{23}L_{12}}{L_{13}}}{1-\frac{L_{32}}{L_{13}}}(N_{21}t)$$

$$=\frac{0.2-0}{1-0}(-25)=-0.2\times25=-5\text{-in. travel R to L}$$

EXAMPLE 11′: For the three-link screw mechanism *Fig.* 1, given $T_{31}=15$-in. travel L to R, $N_{21}=150$ rpm. clockwise, $(L_{21}=0)$, $L_{23}=0.5$-in. LH, $(L_{31}=\infty)$; required the time in minutes in which link 3 will move its 15 inches from right to left.

From Formula G1

$$t=\frac{\frac{L_{23}}{L_{31}}-1}{L_{23}-L_{21}}\,\frac{T_{31}}{N_{21}}=\frac{0-1}{-0.5-0}\times\frac{15}{150}$$

$$=2\times\frac{15}{150}=0.2\text{ min. }=12\text{ sec}$$

EXAMPLE 11″: For the three-link mechanism, *Fig.* 2, given $T_{31} = -15$-in. travel, R to L, $N_{21} = 60$ rpm, clockwise, $L_{21} = 0.15$-in. LH, $L_{23} = 0.3$-in. RH, ($L_{31} = \infty$); required the time of the travel.

From Formula G1

$$t = \frac{\frac{L_{23}}{L_{31}} - 1}{L_{23} - L_{21}} \frac{T_{31}}{N_{21}} = \frac{0-1}{0.3-(-0.15)} \frac{-15}{60}$$

$$= \frac{1}{0.45} \times \frac{1}{4} = 0.555\text{-min} = 33.3 \text{ sec}$$

EXAMPLE 11‴: For the three-link screw mechanism, *Fig.* 4, given $L_{21} = 0.75$-in. LH, $L_{23} = 20$ in. RH, $L_{31} =$ 0.4-in. LH, $N_{21} = 50$ rpm clockwise, $N_{31}t = 1000$ revs. counterclockwise; required the time in which link 3 turns 1000 times relative to link 1.

1. From Formula A2

$$T_{31} = (N_{31}t)L_{31}$$

$$= (-1000)(-0.4) = 400\text{-in. travel L to R}$$

2. From Formula G1

$$t = \frac{L_{23} - L_{31}}{L_{31}(L_{23} - L_{21})} \frac{T_{31}}{N_{21}} = \frac{20-(-0.4)}{-0.4[20-(-0.75)]} \frac{400}{50}$$

$$= \frac{20.4}{-8.3} \times 8 = -19.662 \text{ min} = -1179.7 \text{ sec}$$

The fact that t comes out negative indicates that for the given leads and the given sense of rotation of link 2 relative to link 1, link 3 cannot rotate counterclockwise relative to link 1.

Guide to the Use of the Formulas

Problem:	Given:	To find:	Use formulas:
1	Lead Angular displacement	Travel	A
2	Lead Travel	Angular displacement	A
3	Angular displacement Travel	Lead	A
4	2 Travels	3rd Travel	B
5	2 Angular displacements	3rd Angular displacement	C
6	3 Leads 1 Angular displacement	2 Other angular displacements 3 Travels	D for an angular displacement C for 3rd angular displacement A for 3 travels
7*	3 Leads 1 Travel	2 Other travels 3 Angular displacements	F for 2nd travel B for 3rd travel A for 3 angular displacements
8	2 Leads 2 Corresponding angular displacements	3rd Lead 3rd Angular displacement 3 Travels	H for 3rd lead A for 2 travels corresponding to given leads B for 3rd travel C for 3rd angular displacement
9	2 Travels 2 Corresponding angular displacements	3rd Travel 3rd Angular displacement 3 Leads	B for 3rd travel C for 3rd angular displacement A for 3 leads: I to check
10*	2 Leads Travel corresponding to the unknown lead Angular displacement corresponding to one of the given leads	Unknown lead 2 Unknown travels 2 Unknown angular displacements	K for unknown lead A for travel corresponding to given angular displacement and corresponding lead B for 3rd travel A for angular displacements
11*	3 Leads 1 Travel Angular velocity corresponding to one of the unknown travels	Time in which the given travel will take place	G
12	2 Travels Corresponding angular velocities Lead corresponding to the unknown travel	Time in which the travels will take place	J

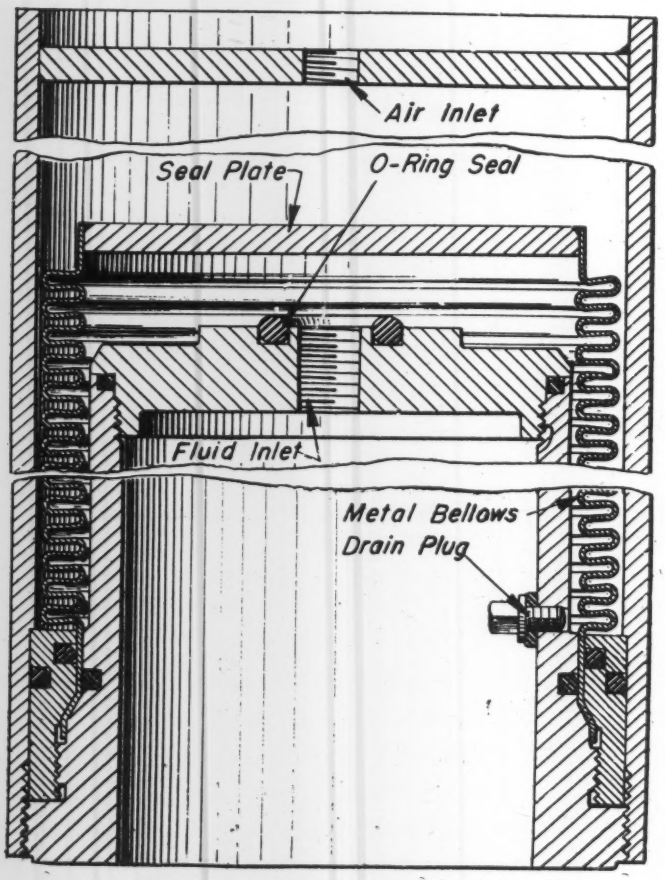
*See also corresponding worked examples.

Noteworthy Patents

Accumulator Has Safety Seal

A HYDRAULIC storage accumulator which prevents collapse or rupture of the actuating bellows on extreme changes in pressure or even total loss of pressure is covered by patent 2,365,994 recently assigned to Electrol Inc. This compressed air type accumulator shown in the accompanying illustration is so designed that complete removal of hydraulic pressure traps an amount of liquid within the bellows sufficient to resist collapse.

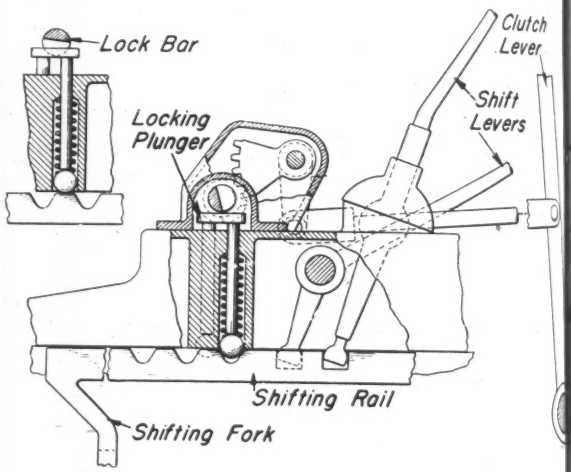
For operation, and with the bellows full of hydraulic fluid, air under pressure is introduced into the upper chamber. This may be of any suitable pressure—300, 600 or even 1000 pounds per square inch as required—so that as the air is compressed by expansion of the bellows during operation, the accumulated pressure reaches the maximum desired in the system. On rapid release of fluid from the accumulator through operation or leakage, the seal plate is forced downward with the bellows until it seats against an O-ring seal. This action traps the oil remaining within the unit to prevent further loss and subsequent collapse of bellows.



This tubular hydraulic system accumulator will sustain a complete loss of fluid without collapse of the bellows

Locks Shifting Forks During Operation

A NEW shifting rail mechanism for heavy-d change-speed transmissions automatically and p tively locks the shifting rails in mesh position as the cl throw-out lever is actuated. This design is covered



Positive lock of the detents in this shifting mechani provides against displacement in operation

patent 2,368,139 recently assigned to the Internatio Harvester Co. Regardless of any change in the positi of the clutch lever created by clutch wear over a peri of time, the cam type locking arrangement functions su stantially unaffected.

Detent notches in the shifting rails of this mechanis shown in the accompanying illustration are so designe that the rail may be moved, shifting the spring-loade ball out of and into the detents, with maximum ease. was found, however, that locking action in a detent mec anism of this type that was mild enough to permit eas shifting was sometimes insufficient to retain the ra against displacement under severe duty conditions. T maintain ease of shifting and assure positive lock of th rails, a cam type lock bar and locking plunger are utilize in this unit to hold the balls in their proper detents un power is removed from the transmission by release of th clutch lever. Movement of the lever rotates the ca lock bar into release position by means of a push ro and gear segment. Rails can then be shifted in and out gear as desired.

Of particular advantage in this mechanism is the pr vision for clutch wear. As wear takes place, the opera ing lever moves further to the left and this in turn ro tates the lock bar counterclockwise to a greater degree Approximately 180 degrees of wear take-up in this manne is possible without disturbing the locking or release func tions of the device.

MACHINE DESIGN'S

MATERIALS WORK SHEET

FILING NUMBER
14.02

"K" Monel*

AVAILABLE IN: Hot-rolled or forged rod and bar, cold-drawn rod, bar and wire, hot-rolled and cold-rolled strip, tubing, sheet and plate

ANALYSIS:

Ni	Cu	Al	Fe	Mn	Si	C	S
66	29	2.75	0.9	0.85	0.5	0.15	0.005

PROPERTIES

ULTIMATE STRENGTH
(psi)

Rod and Bar	
Hot-rolled, as-rolled	90-120,000
as-rolled, age hardened	140-160,000
Forged, as-forged	90-120,000
as-forged, age hardened	140-165,000
Cold-drawn, soft, quenched	90-110,000
soft, age hardened	130-150,000
as-drawn,	100-135,000
as-drawn, age hardened	140-170,000
Strip	
Cold-rolled, soft, quenched	90-105,000
soft, age hardened	130-150,000
half-hard	125-145,000
half-hard, age hardened	150-180,000
full-hard	145-165,000
full-hard, age hardened	170-200.000
Wire	
Cold-drawn, soft, quenched	90-110,000
soft, age hardened	130-150,000
spring temper	144-175,000
spring temper, age hardened	160-200,000

YIELD STRENGTH
(.2% offset, psi)

Rod and Bar	
Hot-rolled, as-rolled	40- 90,000
as-rolled, age hardened	100-120,000
Forged, as-forged	40- 90,000
as-forged, age hardened	100-125,000
Cold-drawn, soft, quenched	40- 60,000
soft, age hardened	90-110,000
as-drawn	70-100,000
as-drawn, age hardened	100-130,000
Strip	
Cold-rolled, soft, quenched	50- 65,000
soft, age hardened	90-110,000
half-hard	85-105,000
half-hard, age hardened	110-130,000
full-hard	105-120,000
full-hard, age hardened	125-145,000
Wire	
Cold-drawn, soft, quenched	40- 60,000
soft, age hardened	90-110,000

ELONGATION IN 2 INCHES
(per cent)

Rod and Bar	
Hot-rolled, as-rolled	45-25
as-rolled, age hardened	30-20
Forged, as-forged	40-25
as-forged, age hardened	30-20
Cold-drawn, soft, quenched	45-35
soft, age hardened	30-20
as-drawn	35-13
as-drawn, age hardened	30-15
Strip	
Cold-rolled, soft, quenched	45-25
soft, age hardened	25-10
half-hard	20- 5
half-hard, age hardened	15- 3
full-hard	8- 2
full-hard, age hardened	10- 2
Wire	
Cold-drawn, soft, quenched	45-30
soft, age hardened	30-15

BRINELL HARDNESS
(3000-kg load, 10-mm ball)

Rod and Bar	
Hot-rolled, as-rolled	140-240
as-rolled, age hardened	265-300
Forged, as-forged	140-240
as-forged, age hardened	265-310
Cold-drawn, soft, quenched	140-180
soft, age hardened	240-280
as-drawn	175-260
as-drawn, age hardened	265-320

IZOD AND CHARPY IMPACT STRENGTH
(ft lbs)

	Izod	Charpy U-Notch
Hot-rolled	120	170
Hot-rolled, age hardened	40‡	61‡
Cold-drawn	56‡	71‡
Cold-drawn, age hardened	26‡	42‡

‡Specimen fractured completely

MACHINE DESIGN is pleased to acknowledge the collaboration of The International Nickel Company Inc. in this presentation.

* Tradename.

ELEVATED TEMPERATURE PROPERTIES OF HOT-ROLLED MATERIAL

(short-time tests)

Temp. (deg F)	Yield Strength (.2% offset, psi) As Rolled	Yield Strength (.2% offset, psi) Age Hardened	Tensile Strength (psi) As Rolled	Tensile Strength (psi) Age Hardened	Elongation in 2 inches (%) As Rolled	Elongation in 2 inches (%) Age Hardened
Room	49,000	111,000	97,000	160,000	44	23.5
200	45,000	108,000	96,000	150,000	42.5	23.5
300	43,000	106,000	94,000	148,000	44.5	25
400	44,000	103,000	92,000	149,000	42	24
500	42,000	108,000	91,000	146,000	43.5	24
600	36,000	105,000	94,000	146,000	39.5	23
700	38,000	103,000	88,000	135,000	33	16.5
800	39,000	105,000	87,000	124,000	29.5	8.5
900	39,000	98,000	82,000	109,000	19	5.5
1000	42,000	92,000	72,000	95,000	13.5	3
1100	41,000	84,000	70,000	84,000	12	2
1200	44,000	80,000	63,000	80,000	2.5	1.5
1300	34,000	48,000	45,000	59,000	9.5	3.5
1400	17,000	30,000	36,000	45,000	22.5	8
1500	.....	8,000	30,000	33,000	32.5	15
1600	.....	.....	15,000	21,000	53	23
1700	.....	.....	13,000	12,000	56	36
1800	.....	.....	10,000	6,000	65.5	47.5
1900	.....	.....	.....	4,000	...	61
2000	.....	.....	.....	3,000	...	81.5

LOW-TEMPERATURE PROPERTIES OF COLD-DRAWN, AGE-HARDENED MATERIAL

Temperature (F)	Yield Strength .2% offset (psi)	Tensile Strength (psi)	Elongation in 2 inches (%)	Reduction of Area (%)	Impact* (ft lbs
Room	125,900	157,300	15.5	37.4	27
−110	134,600	171,550	17.3	41.1	27
Room**	125,850	157,350	14.8	37.2	26

*Impact tests made in a 225 ft-lb capacity Charpy machine using a standard Izod V-notch specimen.

**Cooled to and held at —110 degrees Fahr. for several hours prior to testing at room temperature.

ENDURANCE LIMIT† OF POLISHED SPECIMENS

(for 10^8 cycles, psi)

Soft (quenched from 1450 F)	37,500-41,5
Hot-rolled	41,000-49,0
Hot-rolled, age hardened	44,500-58,0
Cold-drawn, as-drawn	43,000
Cold-drawn, stress-equalized annealed 525 F, 3 hrs	42,000-46,5
Cold-drawn, age hardened	41,000-59,0

†Determined at room temperature on flat strip in special testi machine operated at 10,000 revolutions per minute and design so that the strip is subjected to alternate back and forth bending a flat spring.

PHYSICAL CONSTANTS

Weight (lb per cu in.)	0.306
Specific Gravity	8.47
Melting Range (F)	2400-2460
(C)	1315-1350
Mean Specific Heat (btu/lb/deg F) 70-750 F	0.127
(cal/gm/deg C) 20-400 C	0.127
Mean Coef. of Thermal Expansion (in./deg F)	
32-212 F	0.0000078
70-570 F	0.0000083
70-1110 F	0.0000089
Mean Coef. of Thermal Expansion (in./deg C)	
25-100 C	0.000014
25-300 C	0.000015
25-600 C	0.000016
Thermal Conductivity	
(btu/sq ft/hr/deg F/in.) 32-212 F	130
(cal/sq cm/sec/deg C/cm) 0-100 C	0.043
Elecerical Resistivity (ohms/cir mil ft) 32 F	350
(microhms/cu cm) 23 C	58.1
Electrical Resistivity Temperature Coef.	
(per deg F) 68-212 F	0.00010
(per deg C) 20-100 C	0.00018
Magnetic Transformation	
(deg F) soft quenched	below −210
age hardened	below −150
(deg C) soft quenched	below −150
age hardened	below −100
Modulus of Elasticity in Tension (psi)	26,000,000
in Torsion (psi)	9,500,000
Poisson's Ratio (estimated)	0.32

CHARACTERISTICS

A heat-treatable, corrosion-resistant wrought alloy of nickel, copper and aluminum, "K" Monel combines the excellent corrosion resistance of Monel with strength and hardness greater than those of the latter alloy. Its strength compares with that of heat-treated alloy steel. It is nonmagnetic and retains its nonmagnetic and corrosion-resisting qualities in the fully hardened condition and at subnormal temperatures. Due to its good spring properties, together with resistance to wear and to oxidation and damage under electrical contact conditions, it is used to advantage in the electrical field. It has higher elastic properties and greater fatigue strength than Monel.

APPLICATIONS

"K" Monel is employed where the high corrosion resistance of Monel is required plus greater strength and hardness. Typical applications are: Marine pump shafts and wearing sleeves; oil pump drop and seat valves, valve disks and pump rods; diesel engine fuel-oil injection-valve seats and needles; ball bearing balls, races and cones; roller chain, link studs; check-valve balls, shock absorber plungers, electrical contact parts, heat-treated wire springs, power cable sheathing, doctor blades, nonmagnetic instrument parts, high-torque speed-boat shafting, low-temperature service bolts, screws, machine screws, rivets, lock washers, etc.

FABRICATION

MACHINABILITY:

Although most readily machined in the annealed state, "K" Monel may be considered commercially machinable in Brinell hardnesses up to 275. Harder material can be machined at slower speeds with especially hard tools (cemented carbides) but this is not economical and usually can be avoided by doing at least the bulk of the machining before the material is age hardened. When the machined part is to be used under corrosive conditions, a good smooth finish should be specified because rough, torn surfaces provide focal points for acceleration of corrosion.

The regular high-speed steels and high-speed steels plus cobalt referred to as super high-speed steels are satisfactory cutting materials. Cast nonferrous and cemented-carbide cutting tools are satisfactory when used under conditions affording a rigid tool set-up.

A suitable cutting lubricant should be used in all machining work on this alloy because it is characteristically "sticky", tending to gall or build up on tools. Sulphur-bearing cutting oils, copiously force-fed to the cutting edge of the tool, are recommended for high-speed steel tools. A coolant of soluble oil and water consisting of one part emulsion to ten parts water is suggested for cast nonferrous and cemented carbide tools. All sulphur or lead-bearing cutting oils must be removed thoroughly before the material is subjected to thermal treatment. Sufficient stock should be allowed to insure overall machined finish on all hot-rolled bars. Recommended oversize allowances are given in the following table:

Allowances for Finish Machining of Hot-rolled Products

Size (inches)	Allowance for Rounds	Allowance for Flats, Squares and Hexagons
Up to 7/8 incl.	1/8-in.	1/8-in.
to 1 7/8 incl.	1/8-in.	3/16-in.
to 2 7/8 incl.	3/16-in.	3/16-in.
to 4½ incl.	1/4-in.	3/16-in.

Note—Allowance for rounds is made on the diameter; allowance for flats, squares and hexagons is made on each side.

DRILLING:

Drills with polished flutes are preferable, being reground as soon as signs of dulling appear. Cobalt high-speed steel drills (super-high-speed) are superior to regular high-speed tool steels. In hand feeding, sufficient continuous pressure is required to keep the cutting edge of the drill underneath the metal constantly. If the drill is permitted to dwell, it will polish and harden the metal at the base of the hole, not only making it difficult to resume cutting, but dulling the drill and sometimes resulting in breaking the drill when the cutting edge does dig in. A copious amount of sulphurized cutting oil should be flowed onto the cutting edge of the drill. Suggested feeds and speeds for drilling unhardened "K" Monel are listed in the following table:

Suggested Feeds and Speeds for Drilling

Drill Size (inches)	Speed (ft per min)	Speed (rpm)	Feed per Rev. (in.)
1/8	25	765	0.002
1/4	30	460	0.003
1/2	30	230	0.005
3/4	30	155	0.007
1	20	75	0.009
1 1/2	20	54	0.010
2	20	38	0.012
2 1/2	20	30	0.012
3	20	25	0.012

REAMING:

Spiral-fluted, high-speed steel reamers with narrow lands and well-polished flutes are recommended, being kept sharp at all times. Adequate lubrication with sulphurized oils is necessary to prevent digging and chattering. Reaming feeds are approximately twice the recommended drilling feeds for the same size holes. Reaming operations should not be "pushed" because the metal is apt to tear and wedge between the cutting edges of the reamer. Amount of material to be removed by reaming varies with the hole size. Recommended amounts of unhardened "K" Monel to be removed by reaming in various size holes are listed below:

Hole Diam (inches)	Material to be Removed
1/8 to 1/4	0.005-in. on diam
1/4 to 1/2	0.005 to 0.008-in. on diam
1/2 to 1	1/64-in. on diam
1 to 2	1/64 to 3/32-in on diam

TAPPING:

Because of the alloy's characteristic toughness, tap-drill sizes specified should be slightly larger than those generally considered standard. A good rule is to specify a tap-drill size that will result in a 75 per cent tapped thread. Actually, inasmuch as the material will flow into the roots of the tap threads, what is essentially a full-depth thread results.

Unheat-treated material is tapped at approximately 10 to 15 feet per minute. Particularly when high-nickel alloys are used for both the male and female threaded parts, good clean accurate threads are essential because these alloys are not good bearing metals against themselves. If dull taps are used, the poorly formed threads resulting may cause serious seizure of the threaded parts.

Some tap manufacturers have developed special taps for the tough, stringy alloys and these can be used to advantage. Because of the tendency of this alloy to gall on the tap, a good cutting lubricant copiously applied is essential.

GRINDING, POLISHING AND BUFFING:

It is of great importance when performing these operations to avoid excessive heating because this would affect the hardness of the material. For this reason, grinding of hardened material is done under water or other liquid coolant. Because it is nonmagnetic, "K" Monel cannot be held in magnetic chucks for surface grinding. Having greater hardness than Monel, it will take a higher polish.

FORGING:

This material can be forged in dies or by hand methods into almost any shape that can be forged in steel. Forged parts are stronger than those of bronze or of unheat-treated carbon steel. Success in forging depends largely on proper heating. Commercial forging is done between 2150-1700 degrees Fahr. Light forging is done down to 1300 degrees Fahr. to produce high tensile parts. Extreme care must be exercised in working the material below 1600 degrees Fahr. Heavy forging, drop forging and bending are best effected at temperatures ranging from 1900 to 2150 degrees Fahr. Being stiffer than steel at forging temperatures, "K" Monel requires more powerful machines than does steel for comparable forging operations. "Overhauled" (outer oxide-containing skin removed) material should be specified for drop forged parts.

(*Concluded on next Page*)

COLD WORKING:

In the soft (quenched) condition, this material can be drawn, formed, upset, bent, swaged or otherwise cold worked. More power is required than in forming copper, brass, aluminum, mild steel and Monel. However, with proper tooling, the high ductility of the material permits severe deformations without damage. Increases in tensile strength due to cold working and cold working plus age hardening are shown in the following table:

Nominal Tensile Strength of Cold-Worked and Cold-Worked, Age-Hardened "K" Monel

Amount of Reduction (per cent)	Cold-Worked (psi)	Cold-Worked, Age-Hardened (psi)
0	100,000	150,000
10	110,000	155,000
20	120,000	165,000
40	145,000	180,000
60	160,000	190,000

WELDING:

Welding can be done by either oxyacetylene or metal arc. After heat treatment, properties of the weld are not as high as those of the parent metal because the weld is not subjected to cold work. Like the parent metal, however, the weld is nonmagnetic. After welding, thermal or chemical (passivation) treatments are not required to retain or restore corrosion resistance. The coefficient of thermal expansion of "K" Monel is practically the same as that of steel. Thus, warping and buckling resulting from a welding operation is essentially the same as for a similar construction of steel.

SILVER BRAZING AND SOFT SOLDERING:

Both processes can be used and of course joints made by silver brazing are stronger than those that are soft soldered. The oxide film generally present on "K" Monel must be thoroughly removed by mechanical (emery cloth or wheels) or chemical (pickling) means before attempting any brazing or soldering. A special flux is recommended for silver brazing. Acid base fluxes are required for soft soldering as rosin is not sufficiently active.

Strength of a properly made silver-brazed joint should be approximately 50,000 pounds per square inch in tension and 30,000 pounds per square inch in shear at room temperature. These values can be used in design calculations with a factor of safety of five. Maximum temperature to which silver-brazed joints can be expected to carry an appreciable load is 600 degrees Fahr. and at that temperature their tensile strength is about 50 per cent of its value at room temperature.

HEAT TREATMENTS

ANNEALING:

Where the material must be softened for machining or further cold working, annealing is required. This is best done by heating to proper temperature for prescribed periods of time and quenching in a bath of water to which has been added 2 per cent by volume of denatured alcohol. Softening is effected by holding at temperatures ranging from 1450 to 1800 degrees Fahr. for specific time periods and then quenching. It is extremely important that cutting lubricants or drawing compounds be removed completely before subjecting the material to annealing temperatures.

AGE HARDENING:

This material is hardened by a single heat treatment consisting of aging at the required temperature. Parts made of the soft material, such as forgings, annealed or hot-rolled rods, cold-drawn rods over 1½ inches in diameter, and soft temper wire or strip can be hardened by holding for 16 hours at 1080 to 1100 degrees Fahr., followed by furnace cooling at a rate of not more than 15 degrees Fahr. per hour down to 900 degrees Fahr. From thence on to room temperature cooling may be effected at any rate.

Moderately cold-worked parts such as cold-drawn rod, half-hard strip, cold-upset pieces and intermediate-temper wire receive the same hardening treatment, possibly being held at temperature for less than the 16 hours prescribed.

Fully cold-worked parts such as those made of full-hard strip, spring wire or heavily cold-worked material generally are held at 980 to 1000 degrees Fahr. for 6 hours or longer, followed by cooling to 900 degrees Fahr. at a rate not exceeding 15 degrees Fahr. per hour. Age-hardened parts can be stress relieved by holding in the furnace at 525 degrees Fahr. for 3 hours.

RESISTANCE TO CORROSION

Like Monel, "K" Monel is resistant to most acids, alkalies, salts, waters, food products, organic substances and atmospheric conditions, both at normal and elevated temperatures. In sea water, it is particularly useful for vital parts where high velocity effects are encountered. However, where exposure in sea water permits accumulation of marine growth or other deposits due to stagnant conditions or low-velocity effects, some local attack may occur. In indoor atmospheric exposure, it either remains bright or undergoes slow fogging. In outdoor urban atmosphere, tarnishing is relatively rapid, developing with time into a green coating. In marine atmospheres a layer of fine corrosion product accumulates. "K" Monel is not useful in highly oxidizing acids such as nitric and nitrous, and has only limited usefulness in sulphurous acid except in cold, dilute solutions.

GALVANIC CORROSION

In neutral salt solutions and waters, "K" Monel, nickel, copper and high copper alloys may ordinarily be coupled without seriously accelerating attack on any of the materials. In sea water it is wise to avoid couples of yellow brass with "K" Monel where the exposed area of the latter is many times that of the brass. With approximately equal areas, or where the area of the "K" Monel is smaller than the brass, such couples are safe.

MATERIAL DESIGNATIONS

In the form of hot-rolled rods, cold-drawn rods, forgings, cold-rolled strip, and cold-drawn wire, "K" Monel is covered by Federal Specification QQ-N-286 and Navy Specification 46N5a. When specifying hot-rolled rods or forgings, qualify by using the wording "Hot-rolled or forged" or "Hot-rolled or forged, heat treated," as desired. When specifying cold-drawn rods, qualify by using the wording "Cold-drawn" or "Cold-drawn, heat treated," as desired.

Press Asso., Inc.

BRONZE is an eternal metal. Time, weather or atmospheric conditions leave it untouched. Evidence of this can be gained from the implements fashioned by primitive man. Many such articles, buried since 2000 B.C., are still in their original condition. This is but one reason why *bronze* is the ideal metal for bearings.

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ASSETS to a BOOKCASE

Plastics in Practice

By John Sasso, managing editor, Product Engineering and Michael A. Brown Jr., Monsanto Chemical Co.; published by McGraw-Hill Book Co. Inc., New York; 185 pages, 7½ by 10½ inches, clothbound; available through MACHINE DESIGN, *$4.00 postpaid.*

For the designer contemplating the use of a plastic for a machine part, a general all-round idea of some of the successful present-day commercial applications would be a great help in making a reasonable selection. This book provides such a background for the reader. Properties, methods of fabrication, design, and cost factors are covered by discussion of more than one hundred "case" studies of practical applications.

A brief introduction sets forth the most essential facts on the various plastics—specifically synthetic organic polymers—along with the various processes. These facts are more fully developed in each particular design covered in the remainder of the text. Each one discussed presents a different combination of problems which were solved, giving the designer the answers to many questions which arise in choosing a specific plastic.

The book is definitely not intended for the plastics chemist or researcher in plastics, but rather for the designer who desires practical readily assimilable and highly usable on-the-job information.

□ □ □

A.S.T.M. Standards—1944

Published by the American Society for Testing Materials, Philadelphia; in three volumes, 6034 pages 5⅞ by 8⅛ inches, cloth or half-leather binding; available postpaid through MACHINE DESIGN, *$10.00 each part, $4.00 each supplement each year. Half-leather binding, $1.00 extra for each part and each supplement.*

An invaluable aid to engineers of all industries engaged in the production, purchase or application of materials, this new A.S.T.M. book of standards contains in their latest form all the Society's widely-used specifications and tests for engineering materials.

The 1944 edition—a year in advance of the normal publication date—contains some 1235 specifications and standard methods of testing, both formal and tentative. Although greatly expanded, the book is again issued in three parts, divisions being as follows:

PART I—METALS: This most widely used part has 2098 pages and 385 specifications and tests. Of these, some 225 cover ferrous metals—steel, cast iron, stainless alloys, etc. The balance apply to nonferrous metals, copper, n nesium, aluminum, etc. Chemical analyses of metals not included since these methods, standards and rec mendations for ferrous and nonferrous metals, are cov in a separately published volume.

PART II—NONMETALLIC MATERIALS—CONSTRUCTION This part, with 1696 pages, has 447 specifications tests. Extensively used data include that on cem brick and building tile, concrete and aggregates, etc. great many new or revised specifications cover port cement, insulating materials, paints, and plywoods.

PART III—NONMETALLIC MATERIALS—GENERAL: Sp ifications and tests in this part, 440 in number, repre many of the newer phases of A.S.T.M. work on such i as plastics, soaps and other detergents, paper and p products, and the like. Most extensive of all, this vol has some 2240 pages covering such materials as fuels troleum products, electrical insulation, rubber, etc.

To keep these volumes up to date, a supplement to part will be issued late in 1945. Each book or set of b is accompanied by a complete "Index of Standards" enable easy and rapid reference.

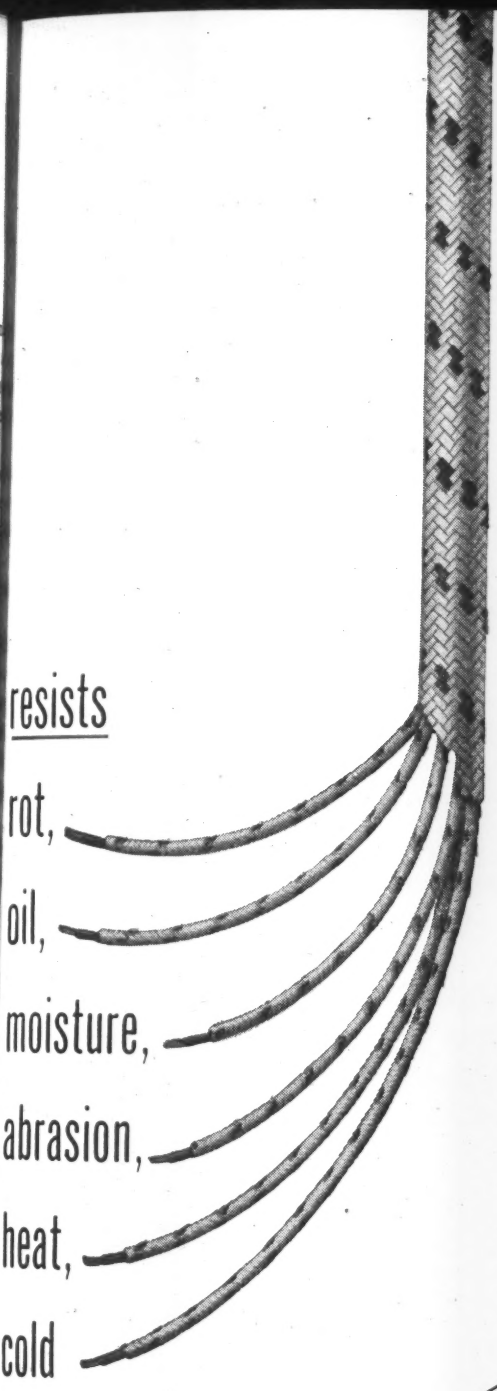
□ □ □

Industrial Electronic Control

By W. D. Cockrell, industrial engineering division, General Electric Co.; published by McGraw-Hill Book Co. Inc., 247 pages, 5¼ by 8¼ inches, clothbound; available through MACHINE DESIGN, *$2.50 postpaid.*

Here is a book written to familiarize engineers with fundamentals of electronic control. To those who that the various and strange-looking components o typical electronic diagram are confusing and beyond grasp of the ordinary man this book is especially direc The author deals only with the basic circuits that com to form an endless variety of complicated arrangem stressing the functions of the different electron tube the circuits. Mechanical components, optical devices, n netic controls, etc., are for the most part eliminate order to avoid confusion.

In a practical, nonmathematical treatment the au covers electron tubes and their construction, circuit c ponents, resistors, capacitors, inductances, transfor basic electronic oscillators, and phase-shift circuits. lowing this the general types of industrial control cir are discussed—power conversion, amplification, tim and switching. Typical examples of commercial electr devices used in the machine tool, printing, proces packaging, and other industries complete the ov analysis, giving a new insight into the increasing pos ties of industrial electronic control.



it's new!

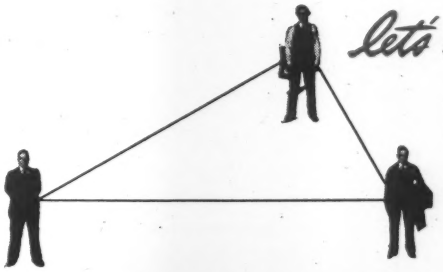
SARAN braid

for better electrical insulation

Cable and wire braid with insulating qualities far superior to any other material—that's the stimulating news brought by this announcement of Saran braid. It marks an important advance in wire protection and provides long-sought answers to many troublesome problems.

Here is a braid that resists abrasion—Saran is permanently tough and durable. It is fungus and mildew proof—long life is the rule even under adverse service conditions. And, more important to the electrical industry, Saran defies moisture and oil—enemies that attack, and soon rot, ordinary cable coverings.

These better insulating properties point to the use of Saran in myriad applications* extending all the way from simple extension cords to intricate wires in radio and radar. If you would like to know more about its value to *you*, write for further details.



let's work it out together

Success in plastics is not a one-man nor even a one-industry job. It calls for the cooperation and combined skill of manufacturer or designer plus fabricator plus raw materials producer. Working together, this team saves time and money and puts plastics to work successfully. Call us—we'll do our part.

PRESENT AND POTENTIAL USES:* Braided covering for wire and cable of all kinds. Especially valuable in guarding against abrasion in such applications as extension cords, etc. Many uses for cable such as household appliance cord that is exposed to moisture and consequent rendering of shock. Resistant to rot caused by entrapped moisture or oil in such applications as automotive wiring.

PROPERTIES: Combines toughness with flexibility even at temperature extremes. Flexural strength, p.s.i. 15,000 to 17,000. Highly resistant to broad range of chemicals. Water absorption less than 0.1. Nonflammable. Excellent electrical insulator. Not subject to distortion of flow at contact points. Available in many colors. Softening point 240°-280° F.

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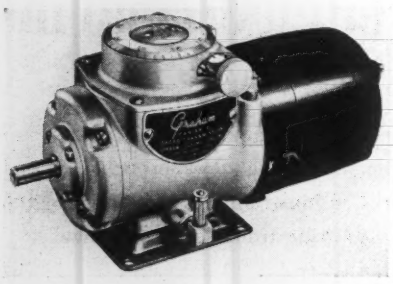
NEW PARTS AND MATERIALS

Three Variable-Speed Drives

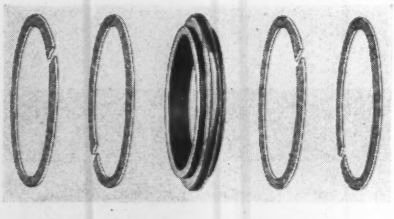
SIMPLICITY IS achieved in three new models of the variable-speed drive offered by Graham Transmissions Inc., 3754 North Holton St., Milwaukee 12. It is available with coupled or built-in motor, straight-line spur or right-angle worm reduction, and controls at the unit or remote. Costly machining has been eliminated in the new



models by the use of die castings. For built-in motors, a simplified mounting eliminates couplings. An improved cam method of speed adjustment gives single-turn straight-line control as standard. The drives range in size from 1/15 to 1½ hp, with speed ranges from 0 to 1100 rpm.

T-Ring Hydraulic Packing

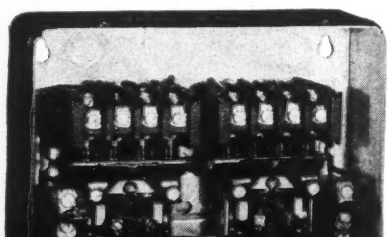
DEVELOPED BY Weatherhead Co., 300 East 131st St., Cleveland, a new hydraulic packing does away with extrusion damage. It consists of a resilient sealing ring of synthetic rubber in a T-section backed up or supported on the side by two nonextrusion ring retainers or guards. The



laminated-phenolic nonextrusion rings are split. When operating pressure is increased, the flange expands radially against the rings, holding them in contact with the surface of the cylinder or piston rod. Diametric variations and finishes of piston grooves do not require nearly the close control otherwise required. When used in the rod-type packing the nonextrusion rings help remove foreign matter from the surface of the rod, thereby eliminating dam age to the sealing member. The packings are recom mended for use as seals in cylinders, swivel joints, stru and numerous other applications including those whe pressures are considerably above current practices.

Magnetic Reversing Starter

SEMI-INTERFERENCE type mechanical interlock i featured in the new starter of General Electric Co., Sche nectady, N. Y. Available in sizes 0 and 1, the new starte is designed for full-voltage starting of squirrel-cage indu tion motors, although it can be used for reversing servi when combined with a reduced-voltage starter. The in terlock prevents closing of one contactor while an arc i maintained on the other, thus averting short circuit throug

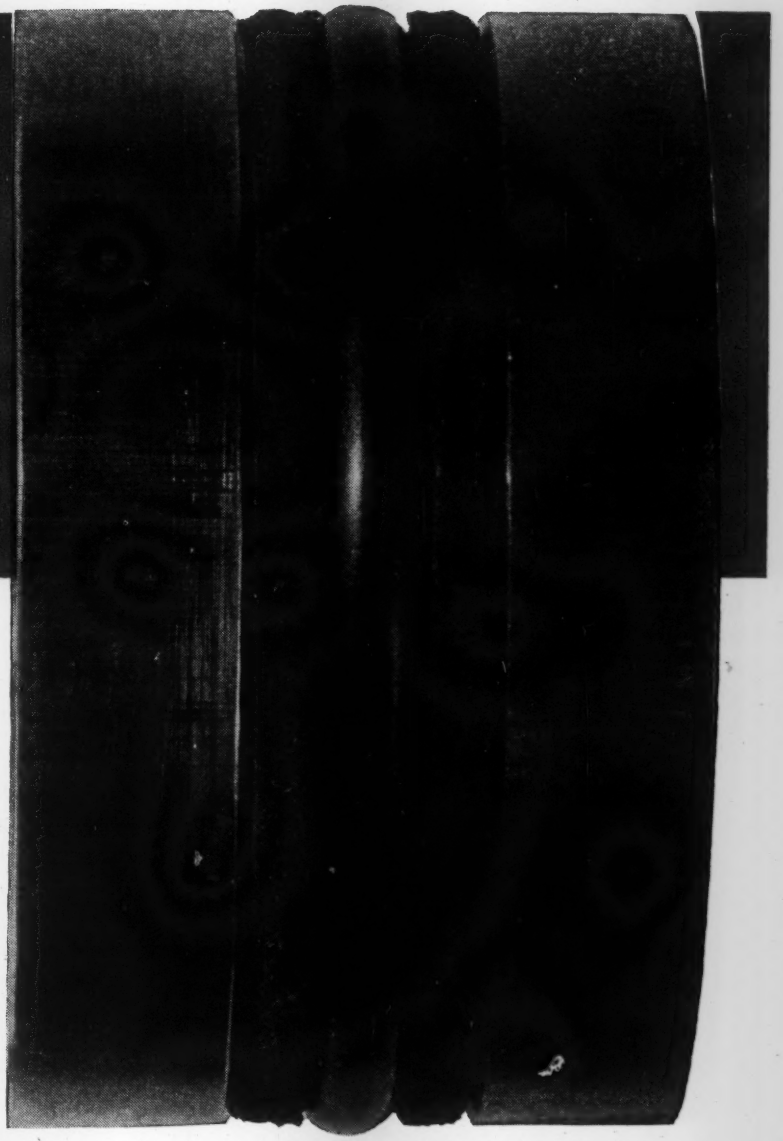


the arc. In addition the interlock arm of the closing con tactor assists the interlock arm of the opening contactor i reaching its fully opened position. Other features includ under-voltage protection when used with a pushbutto station or other momentary pilot-circuit device; under voltage release when used with selector or limit switches and tamperproof, self-contained overload relays allowing motor to operate up to its maximum safe temperature be fore tripping it off the line. Housing of starter is 9⅞ 13⅝ x 4 9/16 in.

Electrode Welds with A-C and D-C

KNOWN AS EutecTrode 28, an electrode recently de veloped by The Eutectic Welding Alloys Co., 40 Worth street, New York 13, is a coated special bronze alloy for arc welding bronze, brass and copper. Containing an un usual combination of metals, the electrode is shielded with

70,000 cycles—without WEAR!



"Photo Courtesy Lockheed Aircraft Corp."

...when VIM leather washers protect "O" rings!

ests by leading aircraft manufac-
rers on hydraulic equipment
acked with "O" rings proved, first,
e need for using VIM leather
ashers to protect the ring, and sec-
ndly, that if so sealed, the packing set
ould withstand more than 70,000 cycles at
500 PSI. No failure, no sign of wear!

When pressure was doubled, the leather
ashers prevented extrusion of the "O"
ings for a minimum of 20,000 cycles.

izes and tolerances have been standard-
ed, specifications now being available on
equest. Low salt content of the washers
voids danger of electrolytic corrosion.

Another evidence of the value of leather as a hydraulic packing material! Houghton makes all standard types of leather packings—"U," cup, flange and "V"—and provides the plus value of engineering design and service. What's *your* packing problem?

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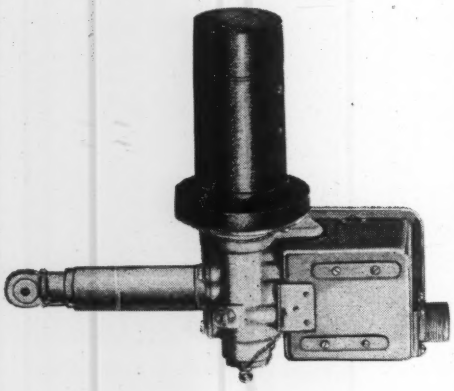
HOUGHTON'S *Engineered* VIM *Leather Packings*

a flux coating that makes it suitable for use either on alternating or direct current. It will deposite dense and tough metal that is a good color match to most types of bronzes. The welded area has substantially the same corrosion resistance as that of the various base metals. The electrode, identified by a light green tip, is available in 1/8 and 3/16-inch diameters. It may also be used for welding copper and brass or joining these metals to steel, cast iron, or nickel alloys, and for overlaying steel or cast iron to provide a good bearing surface.

Dual Linear Actuators

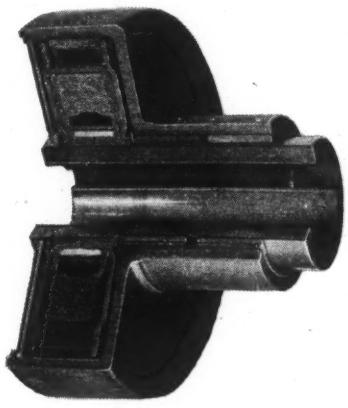
OFFERED BY Foote Bros. Gear & Machine Corp., Dept. NR, 5225 South Western Blvd., Chicago 9, are two dual linear actuators—the primary actuator, powered by a 1/6-hp electric motor; and the secondary actuator (motorless type) which gains its power from the primary by means of a flexible shaft coupling, synchronizing the two units. Both actuators have a linear action of 5 inches at an extension speed of 12 seconds, and a retraction speed of 9 seconds. Limit switches control travel of the screwjack, and stops may be adjusted by a single screw. The two models are capable of handling working loads up to 750 lb with



a static load capacity of 2500 lb. Operating at 8000 rpm from 26 v direct current at 11½ amp, the 1/6-hp motor is equipped with a magnetic brake for instantaneous stops and for preventing gear train from creeping due to vibration. Dimensions of the motorized actuator are 13 x 11 x 4 15/16 in.; weight, 7 lb 1 oz. The shaft driven model is 10 11/16 x 3½ x 3¾ in.; weight, 2 lb 12 oz. The latter may be used separately by driving it from an engine or any remote source of power.

Clutch Offered in Five Widths

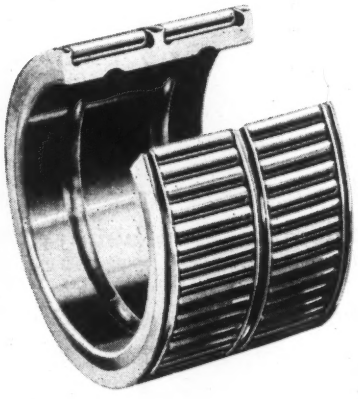
DEVELOPED TO meet requirements for clutches from 1 to 7½ hp, the 450 Series of Type C clutches of Mercury Clutch Corp., Canton 6, O., offers many advantages. Included in these is the inherent "delayed action" which permits the motor to come up to its effective speed instantly and without load. The clutch is of the internal expanding type, with six segmented shoes engaging the inner surface of the ground casing. Actuating force is generated by a small quantity of mercury, sealed wi the clutch, which builds up a hydraulic pressure th applied to the friction shoes. This force varies as square of the rotational speed. When desired, spr are incorporated in the clutch, opposing the centrif



force of the mercury, and thus preventing the engag ment of the clutch until some predetermined speed h been reached. The clutches may be furnished with groove pulley for belt drive, or in the coupling type direct drive. Maximum bore of both driven and drivi members is 1⅛ in. The clutch is only 4½ in. in dia eters and is made in five widths. It is suitable for u with electric motors or internal combustion engines.

Inner Race and Roller Assembly

DESIGNED AS a self-contained unit and made in bo single and double row, the new bearing announced by T McGill Mfg. Co. Inc., Valparaiso, Ind., is similar in sty to the company's established line of Solidend Multirol bea ings. Rounded end rollers give high load capacity; cl tolerance and rigidity improve bearing efficiency and e minate vibration and noise. Races and rollers are through-hardened, high-carbon chrome steel. This ne



type inner race and roller assembly bearing known as Ty IR may be used on applications where parts which ha been heat treated to obtain surface hardness can be u lized as outer raceways. A typical application, accordi to the company, is for constant-mesh gear transmissio

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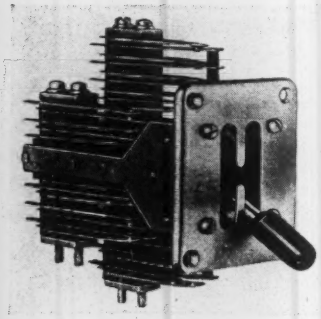
PITTSBURGH 30, PENNSYLVANIA

SPECIAL COLD DRAWN SHAPES SAVE MACHINING

The ground bores of the hardened gears act as outer raceways. Advantage is taken of the small radial space required by this bearing, and the high load carrying capacity under static conditions.

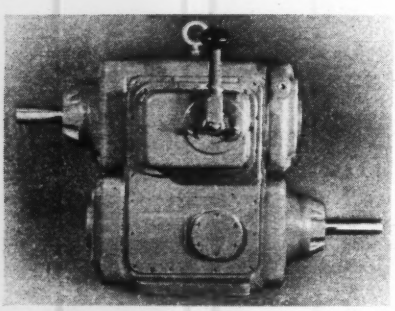
Heavy-Duty Lever Switch



ADDITION OF Series 4500 heavy-duty lever switch to its line has been made by Donald P. Mossman Inc., 612 North Michigan Ave., Chicago 11. Meeting a demand for a multiple - position, multiple-circuit, positive-action lever switch, the new series is available in either a four-position (Series 4504) or a five-position (Series 4505) switch. In all positions, except center (neutral), the action may be locking or nonlocking. In center position it is always locking. Locking or nonlocking action is obtained by using removable stop plates underneath the escutcheon plate which is part of the unit. This action may be changed by selecting the proper stop plate. In addition to its use for the many applications found for the Series 4100 and 6300 switches, the new switches can be utilized for safety selecting switching, substituting the use of four switches where selectivity is required, preventing danger of throwing more than one switch at a time, and emergency transfer of spare equipment in which special locking arrangement prevents using the switch without breaking a seal. The lever switch is also adapted to applications such as motor starting, stopping, reversing and speed control, hoist and crane control, equalization of multigenerator operation, etc.

Hydraulic Variable-Speed Unit

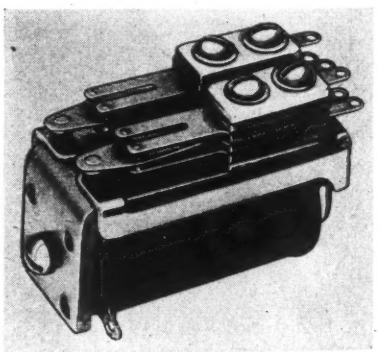
LATEST DEVELOPMENT in the series of hydraulic drive units produced by Portman Machine Tool Co., 70 Portman Rd., New Rochelle, N. Y., is the Model HT-1 hydraulic variable-speed transmission. Of heavy-duty



type, it is intended for use in industrial applications requiring continuous-duty performance under varying conditions of load and speed. Variable speeds available are from zero or full neutral position to maximum n speeds, both forward and reverse. Torque outpu this unit remains constant at all speeds. In additio the hand-lever model, illustrated, various types of co mechanisms are available to suit all applications, inc ing remote control stations. Overall dimensions are x 16¾ x 18½ inches. Diameter of shaft is 1⅜ inc while shaft extension length is 3½ and 4½ inches. Ho powers in which the unit is available include 5, 7½, 15 and 20. Maximum speed is dependent on the sp of electric drive motors or other prime movers, and speeds are usually from 900 to 1700 rpm with this of unit. The transmission illustrated can also be nished with electric drive motors for various el current specifications and to include a base for the mo ing of the hydraulic transmission and the electric tor, starters and other controls suited to the partic application.

Midget Telephone Relay

ONE OF THE smallest of its type, the new mi telephone relay of Potter & Brumfield Mfg. Co. Inc., Linden street, Princeton, Ind., weighs only 1¾ oz. Kn as the "MT" Series, it is constructed compactly for mo ing in limited space. It is sensitive and operates minute current, with twin contacts exerting the high

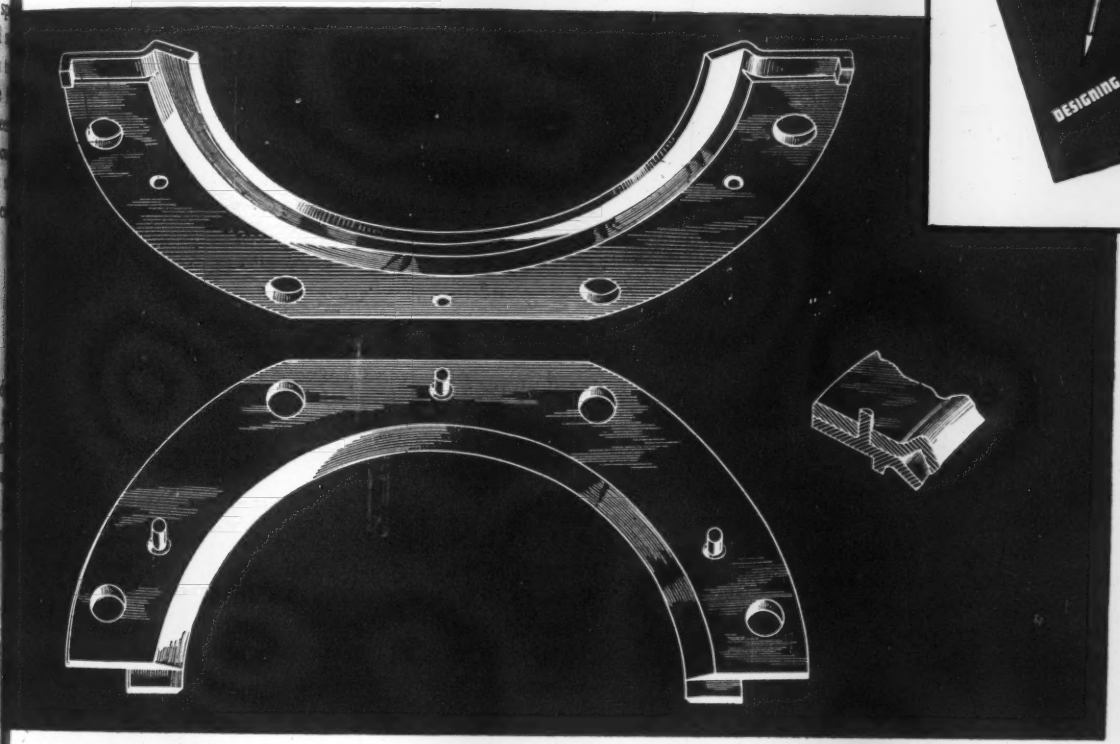


tact pressure needed for closure. Particularly resistant vibration, the relay with two Type C contact assembl measures 1 1/2 x 1 7/32 x 11/16 in. Operating volt is up to 60 volts direct current. Frames are provid with 4 mounting holes tapped 3-48. The relays furnished in all contact arrangements of forms A, B and

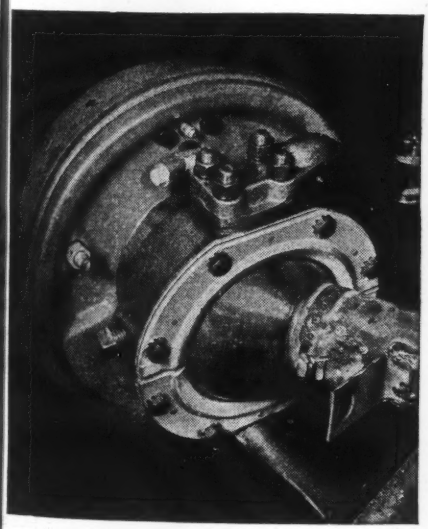
Bottle and Can Counter

NOTABLE IMPROVEMENTS have been made by t Durant Mfg. Co., 1929 North Buffum street, Milwaukee in its new "HF" Productimeter for counting bottles a cans, replacing the former "F" models. These inclu many features such as oilless bearings; accuracy; curve louvered window for reading of figures; strong, mold plastic number wheels; legible black figures on white ba ground; heavy die-cast base with dust-tight metal cov rustproof construction; steel stamping mounting plate; a grey baked enamel finish. The new series is available

DESIGNING FOR DIE CASTING



STUDS



Studs formed as integral parts of a die casting cost less than inserted studs. The need for placing separate inserts in the die is thereby eliminated—speeding production. For best results integral studs should:

1. be sufficiently large in diameter to provide adequate strength (at least ¼" for all except small, light castings)
2. have liberal fillets where they join the casting proper (fillets can be recessed if, otherwise, they prevent proper seating of the mating parts)
3. be threaded only when length does not greatly exceed diameter (consider the use of "speed nuts" with unthreaded-studs)
4. have countersunk or recessed ends when the latter are to be spun over at assembly
5. be cylindrical unless some specific requirement necessitates another shape.

The two zinc alloy die castings shown here illustrate the use of integrally cast studs. These two castings form one half of the grease seal for the universal joints on "Jeep" front axles. Holes are cored in one casting to mate with the integral studs on the other. After a packing is inserted between the castings, the studs are easily headed over — since zinc alloy possesses good ductility.

Additional data on studs, and many other design considerations, appear in our booklet "Designing For Die Casting." To insure that you will get the most for your die casting dollar, ask us —or your die casting source—for a copy of this booklet.

THE NEW JERSEY ZINC COMPANY
160 Front St., New York 7, N. Y.

ZINC
FOR DIE CASTING ALLOYS

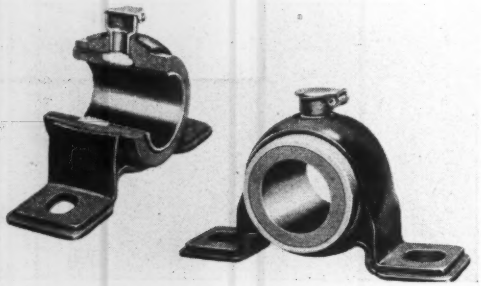
The Research was done, the Alloys were developed, and most Die Castings are specified with

HORSE HEAD SPECIAL (99.99+% Uniform Quality) ZINC

either five or six figures capacity, and equipped with a 6-point star wheel for counting bottles, and a 4-point star wheel for cans.

Bronze Bushed Bearing

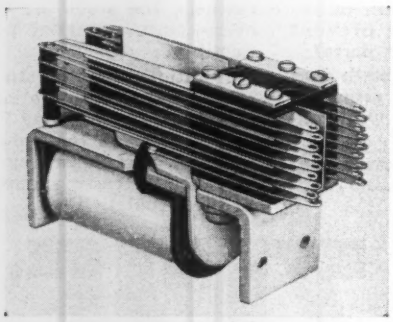
FOR FAN AND blower service, a new bronze-bushed bearing, known as Type F Bronzoil bearing, has been announced by Dodge Mfg. Corp., Mishawaka, Ind. Fully self-aligning, the bearing has a spherical inner housing conforming to a spherical socket in the formed steel outer housing. This permits free self-alignment. A bronze



capillary bushing is used as a liner. This bushing is provided with a shoulder offering a broad, flat surface which is lubricated and serves to reduce friction between bearing and collar. An oil reservoir supplies the required amount of oil as needed. Wick and oil cup are furnished with the bearing. Frontal area of the bearing has been reduced, resulting in greater volumetric efficiency in blower installations.

Multicontact Relays

APPLICABLE to signal, electronic and communication uses where minimum operating currents are important factors, the new Type 20000 relay of R-B-M Mfg. Co., division of Essex Wire Corp., Logansport, Ind., is produced in two sizes: Standard, 4 4/4 x 1 x 1 3/4 or 2 1/2 inches, depending on contact spring assemblies; intermediate, 3 5/8 x 1 x 1 3/4 or 2 1/2 inches. Contact spring assem-



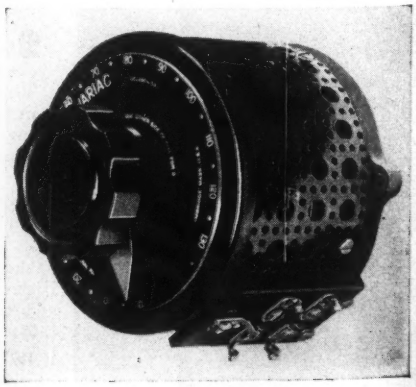
blies of this relay can be furnished in one, two or three stacks, with various combinations, according to circuit requirements, up to 16 springs. Specially treated coils to withstand extreme humidity and prevent fungus growth are available in voltage ranges from 1 1/2 to 28 volts, direct current. This type relay is also available in two-pole double-throw contact arrangement, with current sitive coil operating at 3.2 milliamps pickup and 1 to milliamps dropout. These relays are furnished with q acting, slow dropout and slow pickup armatures.

Arc-Welding Electrodes

NEW ADDITIONS to the line of arc welding el trodes of Allis-Chalmers Mfg. Co., Milwaukee, are Nickel Manganese, Mo Mang Manganese, X2, and electrodes. The A-C Nickel Manganese and A-C Mang Manganese have application in mining, ceme and railroad industries. Characteristics of the dep allow it to work-harden to 550 brinell. Hard-surfac electrodes X2 and X3 are used to protect parts subj to extensive wear; the X2 for severe abrasion and m impact; and the X3 for severe impact and mild abrasi All of the electrodes are available in assorted sizes, first two both bare and coated (the coating being a co bination, suitable for both alternating and direct-curr welders), while the X2 and X3 types are furnished w combination coating only.

Variacs for 400-Cycle Operation

TO ITS LINE of Variacs, General Radio Co., 275 Mas chusetts avenue, Cambridge 39, Mass., has added t Type 60-A. A 400-cycle, 5-ampere model for 115 vo it can be used at any frequency between 400 and 2 cycles per second. Rated at 860 volt-amperes, outp voltages to 135 volts are obtainable with 115-volt inp A new type of brush and radiator construction is u so that brushes, when necessary, can be changed in

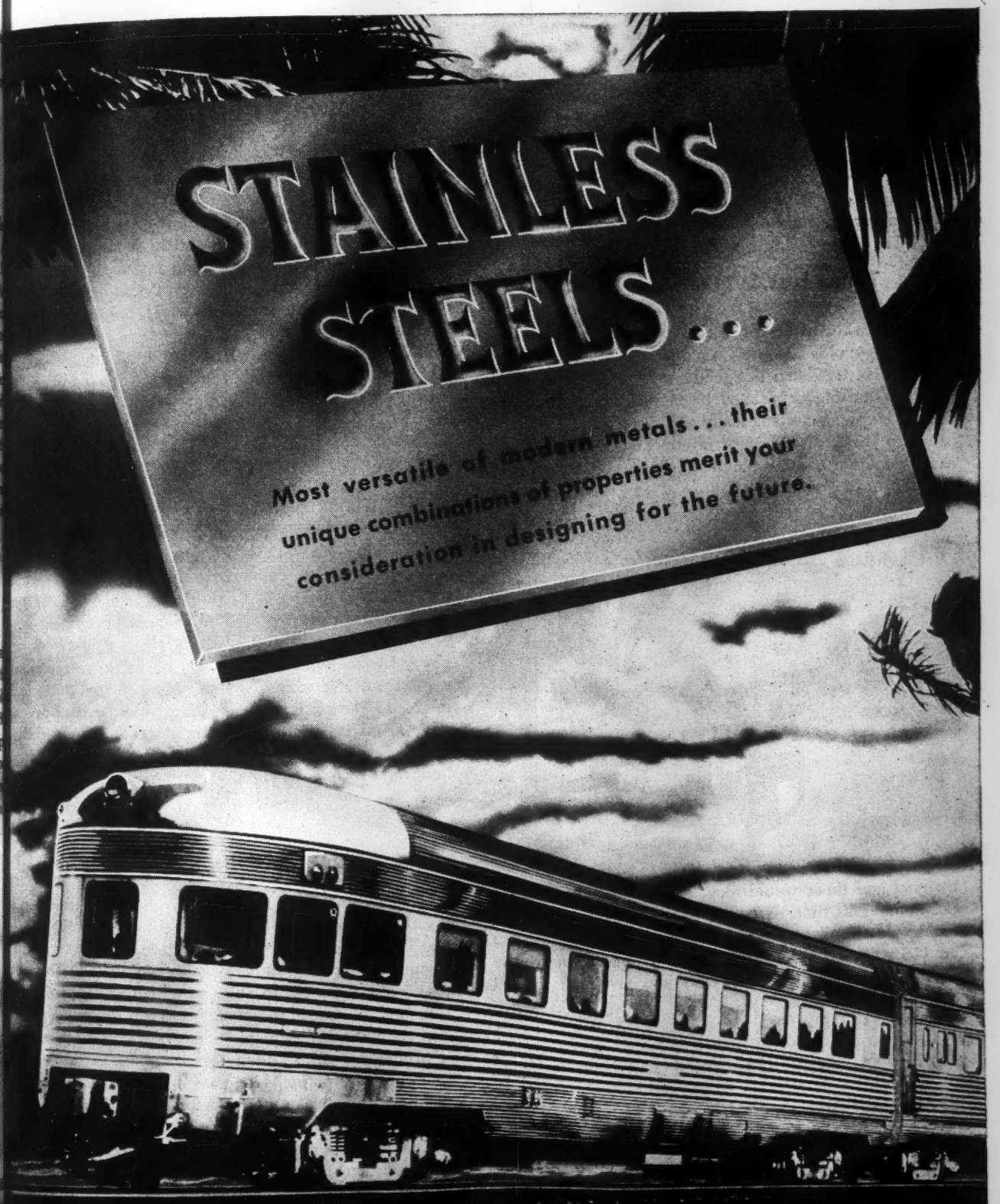


few seconds. The Variac is available either with or wi out case. Overall height is 4⅛ inches; overall diame 5½ inches. Net weight is 3½ pounds with case; 3 pou 2 ounces without case.

Protectors for Machine Parts

THREAD PROTECTORS and dust caps of spiral-wou fiber, kraft paper, or cellulose acetate, under heat-trea compression, are among the latest additions to the line

(*Continued on Page* 170)


STAINLESS
STEELS . . .
Most versatile of modern metals . . . their unique combinations of properties merit your consideration in designing for the future.

● This Streamliner exemplifies the enduring strength and beauty of stainless steel. Characterized by endurance under corrosive conditions, chromium-Nickel stainless steels permit reduction of bulk and dead weight...without sacrifice of strength or safety.

• • •

International Nickel are miners, smelters and refiners of Nickel, an important ingredient of the stainless steels, but do not produce stainless steels. If interested, please communicate with established sources of supply for stainless steels.

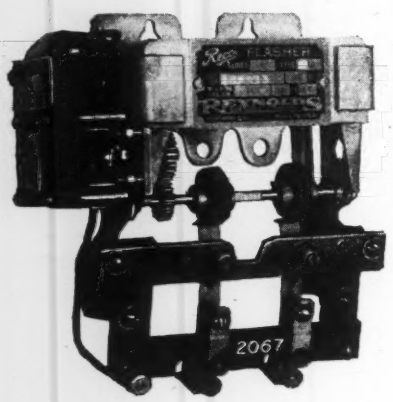
THE INTERNATIONAL NICKEL COMPANY, INC. 67 Wall Street New York 5, N.Y.

(*Continued from Page* 166)

Precision Paper Tube Co., 2033 West Charleston street, Chicago 47. They are constructed for durability in protecting fittings, exposed openings and ends, tubing, and many others from moisture, rust, dirt, grit, dust or damage. These protectors are shaped to the article to be safeguarded—cylindrical, square, rectangular or tapered, crimped, flared or perforated—with tolerances as close as ±.003-inch. Name of part and number, as well as name of manufacturer can be printed in the protector.

Timer Has Synchronous Motor

EQUIPPED with a synchronous motor, the new control timer of Reynolds Electric Co., 2650 West Congress street, Chicago 12, has been designed for controlling operations in which starting is initiated by momentary contact push-button, stopping automatically at preset time. The timer can also be furnished with interlocking controls so that each operation can be completed in correct sequence before the next is started. Failure at any point would post



a signal and timer would recycle automatically to starting position. This timer is equipped with silver contacts and has a two circuit control. Its synchronous motor operates on 115 volts, 60 cycle alternating current. If desired it is available with additional circuits and arranged for other current specifications.

Link Universal Joint

RECOMMENDED FOR hand operation and slow speed power drives, the Piezo universal link joint of Piezoelectric Corp., 110 East Forty-second street, New York 18, can be used in the controls of electrical switchboards, radio, electronic equipment, automatic machinery, valve operation and many other mechanical devices. This new remote control features an adjustable link mechanism to transmit rotary motion around corners, permitting the operation of shafts at angles adjustable from a straight line to a right angle. An important feature of this joint is that the output shaft turns in the exact angular rotation as the input shaft, giving an input turning angle equivalent to the output turning angle. The joint is mounted by means of three screws, holding it in position. Bearing arm, holding the adjustable shaft, may be hinged to any desired position from 0 to 90 degrees, and when in location a h screw holds its position.

Varnished Glass Sleeving

PRODUCED BY William Brand & Co., 276 Fourth enue, New York 10, the varnished glass sleeving sh in the accompanying illustration has many advanta Among these are increased dielectric values, lower a ture-absorption, nonburning, and high temperature re ance. This sleeving is available in four grades: Sin double and triple dips, and the magneto grade. All characterized by permanently-vivid colors, designed facilitate identification and assembly operations. nish treatment insures long-life flexibility, elimina hazards of cracking and splitting. An additional vantage is its nonfraying characteristic.

Plastic-Coated Conveyor Belting

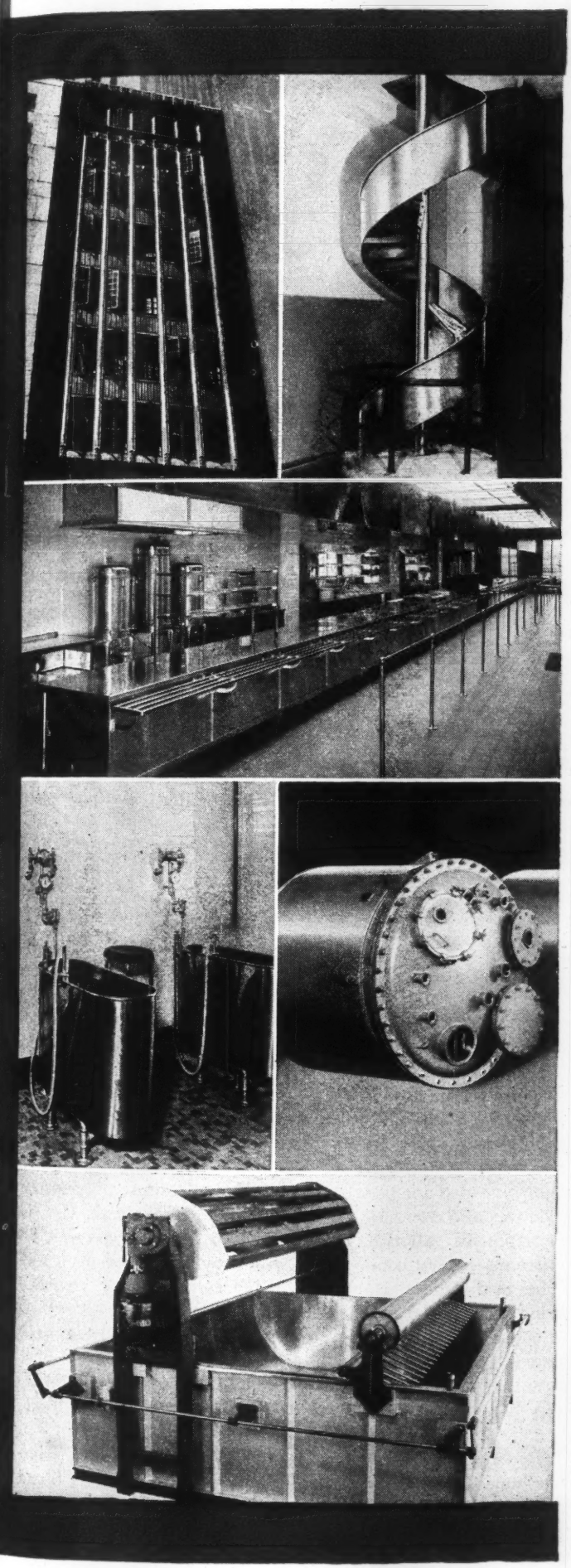
TO MEET THE NEEDS of canning, packing and processing industries for a conveyor belting that is imp ous to oils, greases, moisture, acids and alkalis, PlasTe new plastic-coated conveyor belting has been announ by Buffalo Weaving & Belting Co., 260 Chandler st Buffalo 7. Consisting of a pliable-plastic coating ov woven cotton carcass, the belting has a semismooth, s glossy surface which will not absorb moisture and is e kept clean. Capable of withstanding temperatures to degrees Fahr., it is available in standard colors of re white, and is furnished in three standard construct Regular coat on one side, regular coat on both sides, heavy coat on carrying side with regular coat on pu side.

New Synthetic Development

DEVELOPMENT OF a new synthetic, Chlorinated pol, has been announced by The Union Bay State Ch ical Co., 50 Harvard street, Cambridge, Mass. Avail in metal primer formulations and in powder form, practically identical to chlorinated rubber in flame, m ture and chemical resistance, and in solubility, stab and compatibility with plasticizers. It is recommended a primer for rubber-to-metal adhesion; as an ingredi in adhesives, paints, lacquers, inks, etc.; as an acid alkali-resistant coating for metal and other surfaces; fireproofing and moistureproofing fabrics and other m terials; wherever sound and heat insulation qualities required; and as a plastic wherever inertness to che icals and fireproofness are desired.

Luminous Characters for Inlay

INLAID BAKED enamel characters, protected by bo ground finish, are now obtainable in luminous type, eit phosphorescent or fluorescent. This is an addition to new inlay process for placing durable characters on m panels, chasis, etc. (MACHINE DESIGN, July, 1944, Pa 168) offered by Screenmakers, 64 Fulton street, N York 7. The characters are resistant to abrasion.

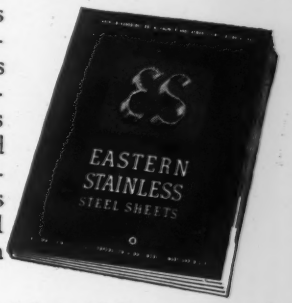


FACTS you want to know about STAINLESS STEELS

Reconversion, limited as it has been to date, points to expanding utilization of Stainless Steels in hundreds of industries for thousands of new applications.

In using to best advantage, the versatility, utility, economy and attractiveness of Eastern Stainless Steels in your business, it's important you know the characteristics and applications of each of the twelve Eastern Stainless standard grades.

Just Published — New 96 Page Catalog



To help you fabricate this superior metal in your industry, Eastern Stainless offers you free, a comprehensive new catalog. This handy manual describes and illustrates the major applications of Stainless Steels and gives much technical data compiled by Eastern Stainless specialists.

Under the classification, "General Processing and Fabrication," the new Eastern Stainless catalog gives valuable information on the following:

SHEARING • JOINING • FORMING
MACHINING • HEAT TREATMENT • FINISHING
DESCALING • CLEANING • PASSIVATING

Almost any question you have regarding Stainless Steels is answered in this up-to-the-minute Eastern Stainless catalog. Be sure and write for your free copy.

EASTERN STAINLESS TECHNICAL SERVICE is of special value to producer and consumer alike, for it relates to all phases of production, processing and fabrication of Stainless Steels. Whatever your problem in Stainless fabrication, performance or new developments, the Eastern Stainless Technical Staff will furnish you with up-to-date information.

JMLCo . B-H1

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STEEL CORPORATION

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Distributors' stock available in most areas.

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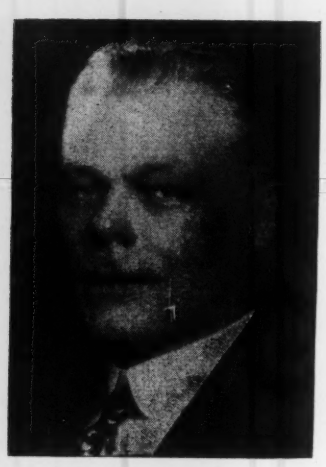


J. F. Joy

J. R. Townsend

Eric W. Peterson

MEN...of...machines

J. F. JOY'S recent election as vice president in charge of engineering of Federal Machine & Welder Co., Warren, O., is considered an important step by the company "as his unusual ingenuity and engineering skill will be reflected in the solution of current problems, as well as in postwar development". Formerly director of engineering, Mr. Joy is internationally known in the engineering field, having served from 1940-1945 in the Office of Chief of Ordnance, Army Service Forces, where he received a citation from the War Department for "successfully developing an improved type of high-pressure packing urgently needed for use with the Field Artillery Material." During this time he was also responsible for many developments important to ordnance equipment. Mr. Joy is the inventor of the Joy coal loader which in 1922 became the first commercially applied continuous gathering mechanism for coal mines. He has headed several prominent companies manufacturing mechanized coal mining equipment, and his inventions have been cited as important factors in reducing cost of coal to the consumer, and increasing overall production. In Russia for several years he was head of the Joy Engineering Co. devoted to the modernization of coal mining in that country.

J. R. TOWNSEND, materials engineer, Bell Telephone Laboratories Inc., is the new president of the American Society for Testing Materials. Completing a term as the vice president of the society, Mr. Townsend has been extremely active in the organization. He has been chairman of Committee B-6 on Die-Cast M
als and Alloys since 1934, is a past ch
man of Committee E-10 on Standa
and is active in the work of various o
groups. Recently he headed a gr
studying the desirability of the soc
extending its work to include the f
of testing parts and assemblies. B
in Baltimore, Mr. Townsend attend
Baltimore City College and Brook
Polytechnic Institute. After experie
with Bethlehem Steel Co., and
Mathematics and Dynamics Branch
U. S. Army Ordnance in World War
in 1919 he became a member of
technical staff of Western Electric
From 1925 through 1944 he was
terials standards engineer at Bell, beco
ing materials engineer in 1945.

ERIC W. PETERSON, who for
past twenty years has had broad exp
ence in industrial engineering and m
chine development, is the new ch
engineer of The Kaydon Engineer

CORROSION RESISTANT • HEAT RESISTANT • COLD RESISTANT

WEAR RESISTANT • CREEP AND IMPACT VALUES

RESPONSIVE TO HEAT TREATMENT • READILY MACHINABLE

Fort Pitt Stainless Steels have been developed to meet the growing demand for corrosion-resisting steels with higher physical properties. Close analytical control and modern technical methods in one of America's most advanced specialty foundries, assure castings of superior quality in every respect. Customers of the Fort Pitt foundry have the advantage of the combined experience of Fort Pitt metallurgists and Porter process equipment engineers in the solution of their corrosion problems. Send us your blueprints. We will gladly supply an estimate and recommend the proper alloy.

PORTER "Better Built" Equipment
Established 1866

FORT PITT STEEL CASTING CO.

Division of H. K. PORTER COMPANY, Inc.

PITTSBURGH 22, PENNSYLVANIA

FACTORIES: McKEESPORT, PA. • PITTSBURGH, PA. • BLAIRSVILLE, PA.
NEWARK, N. J. • NEW BRUNSWICK, N. J. • MT. VERNON, ILL.

Corp. For six years prior to his appointment, he had been chief engineer at Ditto Inc. Previously, he served as industrial engineer with the Remington Arms plant of E. I. du Pont de Nemours Corp., at Ilion, N. Y., developing special production equipment. He also had been connected for five years as supervisory engineer on new machine and product development with The International Business Machines Corp. Mr. Peterson is a graduate of Lowell Institute.

♦

FAYETTE LEISTER has been advanced to the position of engineering manager, Fafnir Bearing Co. He will be in charge of all phases of design and development.

♦

CHARLES CUMA, formerly development engineer of Atlas Imperial Diesel Engine Co., Chicago, has been made chief design engineer on engines for Willys Overland Motors Inc., Toledo, O.

♦

JOHN F. WALLACE, chief executive engineer, aircraft and automotive engineering department, Cleveland Pneumatic Tool Co., Cleveland, has been elected to the company's board of directors.

♦

W. S. JAMES, chief engineer for Studebaker Corp., Detroit, since 1936, has been named director of automotive research for the Ford Motor Co., Dearborn, Mich.

♦

JOHN H. STANG, formerly assistant in the mechanical engineering department of Ohio State university, has been appointed to the staff at Battelle Memorial institute, Columbus, O., and assigned to its Division of Fuels and Research.

♦

W. J. RALEIGH has joined Scott-Atwater Mfg. Co., Minneapolis, as design engineer in charge of design and development of outboard motor magnetos. He resigned as head of the Engine Design Section, National Advisory Committee for Aeronautics, Cleveland.

♦

JOHN A. ROBINSON has been promoted from a checker in the engineering department to assistant chief draftsman of the Buick Motor Division, General Motors Corp., Flint, Mich.

♦

GEORGE C. MCMULLEN has recently been appointed assistant to the president, and vice president in charge of product research and development, Tyson Bearing Corp., Massillon, O. He formerly had been vice president in charge of industrial sales for the company.

♦

ROBERT CASS, formerly chief engineer, has been promoted to assistant to the president of White Motor Co., Cleveland. He will be in close contact with engineering management in his new position.

♦

LLOYD STEARMAN, previously chief engineer, Air Cargo Division, Harvey Machine Co. Inc., Los Angeles, ... vice president of Stearman Engineering Co., Do... Calif.

♦

A. P. FONTAINE has been made director of airc... velopment, Bendix Aviation Corp., Detroit. He ha... assistant to the director of engineering, Consolidate... tee Aircraft Corp., Vultee Field, Calif.

♦

HAROLD M. BURDICK has joined International B... Machines Corp., Endicott, N. Y., as designer. F... he had been associated with Sperry Gyroscope C... search Laboratory, as layout draftsman.

♦

JOHN F. CAMPBELL has been appointed develo... engineer, gas turbine equipment, Weatherhead Co., ... land. He had been chief engineer, fuel injection d... ment, Holley Carburetor Co., Detroit.

♦

HARRY I. HAZZARD, previously development eng... McCulloch Aviation, Milwaukee, is the new chief en... of Salsbury Motors, Los Angeles.

♦

H. E. PRESTON has recently been appointed vice ... dent in charge of engineering, American Engineering ... Philadelphia.

♦

W. E. WICKENDEN, president, Case School of Ap... Science, Cleveland, has been nominated president o... American Institute of Electrical Engineers.

♦

BENJAMIN NICOL ASHTON JR., formerly vice pres... in charge of engineering, was recently elected presid... Electrol Inc. Mr. Ashton has been responsible fo... signs for aircraft hydraulics manufactured by the comp...

♦

JOHN C. STRAUB, who for the last thirteen years ... been associated with the Research Laboratories Div... of General Motors Corp., Detroit, has been appointe... search engineer of American Foundry Equipment ... Mishawaka, Ind.

♦

DR. ZAY JEFFRIES, technical director of General Ele... Co. lamp department, has been elected a vice presiden... charge of the company's new department to be known ... the chemical department.

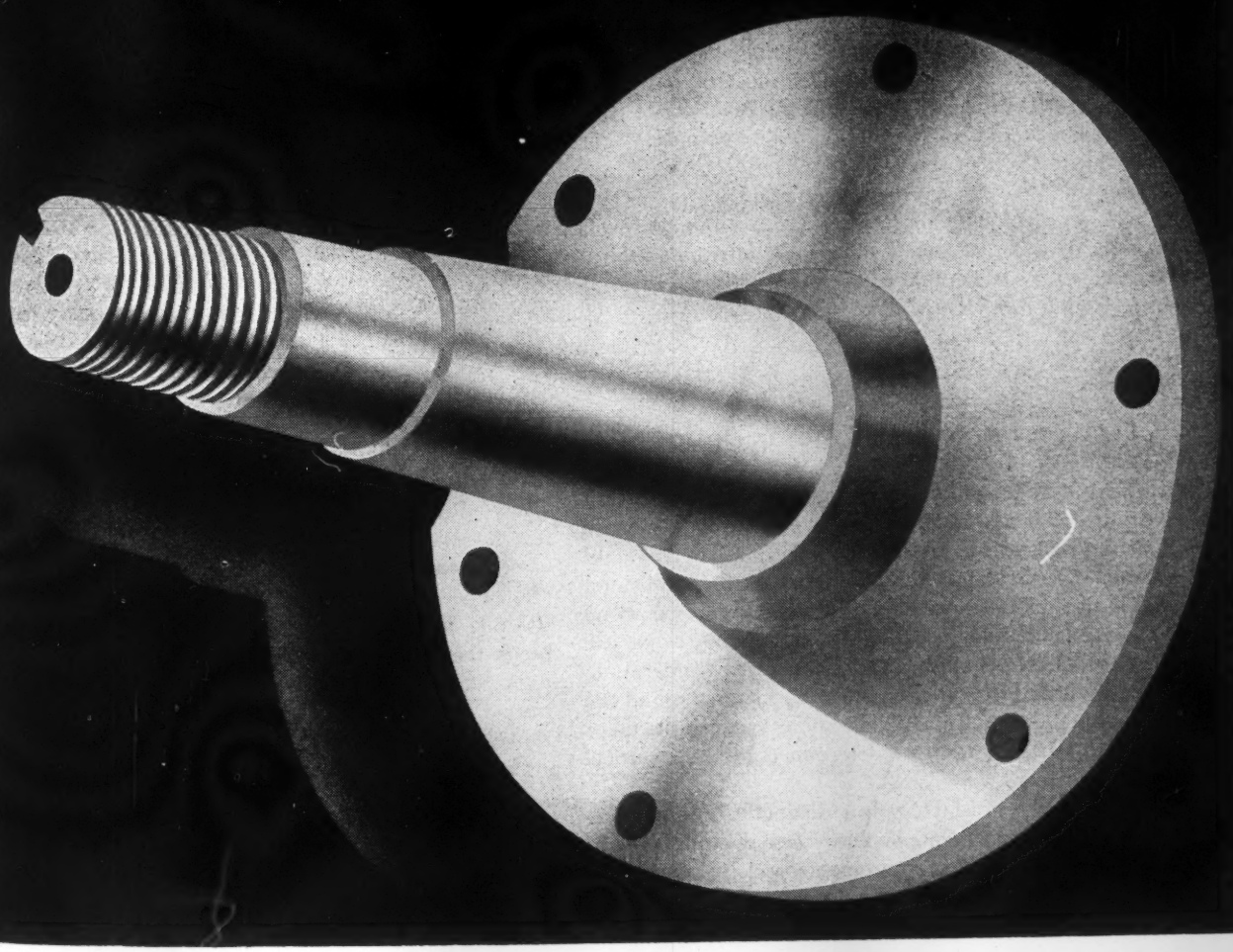
♦

GEORGE STEVEN, formerly chief engineer of the Buf... Works Compressor Division, Worthington Pump & ... chinery Corp., has been appointed executive engineer ... the Buffalo Works of the company. HAROLD W. WEIR ... succeeds Mr. Steven as chief engineer.

♦

HELMUTH G. BRAENDEL, for the past three years ass... ant and then chief development engineer of Contin... Motors Corp., has been appointed chief engineer of ... Wilkening Mfg. Co., Philadelphia.

Molybdenum is an economical preventive of temper brittleness in steel.



IMAX FURNISHES AUTHORITATIVE ENGINEERING ATA ON MOLYBDENUM APPLICATIONS.

ARMY E NAVY

MOLYBDIC OXIDE, BRIQUETTED OR CANNED • FERROMOLYBDENUM • "CALCIUM MOLYBDATE"

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MOLY

Design Abstracts

Controlling High-Speed Aircraft

BLIND-BOMBING radar equipment will unquestionably be developed further for commercial navigational use to assist in direction finding and to remove the hazard of flying into unsuspected mountains or colliding with other aircraft in the same air space.

As air speeds increase to the 400 to 500-mph category, for normal commercial operation, such radar aids will be doubly necessary even under good weather conditions inasmuch as the visibility over or near most of our large cities is only a few miles by reason of the high smoke content in the atmosphere. The 500-mph aircraft must begin to slow down 25 to 30 miles before landing even if approaching at low altitude. Traffic control in airport regions will necessarily be improved to control the approach of such flights with minimized delays and adequate safety. *—From a paper by D. Roy Shoults, Vice President, Bell Aircraft Corp., presented at the recent semiannual meeting of the A. S. M. E. in Chicago.*

Problems of Aircraft Motor Design

IN DESIGNING 400-cycle aircraft motors it is necessary to correlate functions of five different kinds of engineering: Electrical, mechanical, thermal, airflow and lubrication. Individually these functions are complicated by the high speed of operation, better material utilization and varying conditions in which the motors must operate. Usually the electrical studies are given first consideration, followed by fitting the other engineering factors around the basic electrical design. This is desirable because the other functions to a large extent are determined by the electrical output and losses.

Several equally satisfactory but distinctly different mechanical constructions are possible. Usually that used is determined by the basic requirements and by other, fundamentally extraneous, considerations such as available manufacturing facilities, shop practices and individual preferences. Such other considerations add to or detract from a design only to the extent of their influence on the making of individual parts or the assembly of these parts into the completed unit. Whether or not a design is satisfactory is determined wholly by weight considerations and ability to withstand burdens encountered over the range of operating conditions throughout its expected life, without destroying other essential characteristics. The most severe burdens are imposed by plane vibrations. According to specifications vibrations up to 55 cycles per second with double amplitude of 1/16-inch may be expected.

Comparable lightweight shells may be obtained either from low specific gravity materials such as aluminum or magnesium or from stronger high specific gravity materials such as steel but with the sections reduced. Steel shells with reduced sections permit a better overall design, particularly in conventional constructions where accurate dimensions are necessary to maintain the radial location of stators slipped or pressed into the shells. These have same coefficient of thermal expansion as that of the netic iron and therefore the same accurate dimen exist over the entire temperature range. Aluminum magnesium shells have coefficients of thermal expa greatly different from that of magnetic iron. Becau this, satisfactory dimensions at normal temperatures not remain satisfactory and may cause failure throug cessive stresses in the shells and magnetic structures extreme temperatures below normal are approached.

Due to limitations in manufacturing processes the flanges usually are made of low specific gravity mate Internal rabbets should be used to eliminate failure excessive stresses at low temperatures with steel she

At present, only ball bearings are satisfactory but s bearings with special lubrication may be used in th ture. Bearings of the minimum size necessary for r and thrust loads and the specified life should be use prevent excessive friction torque at low temperatures.

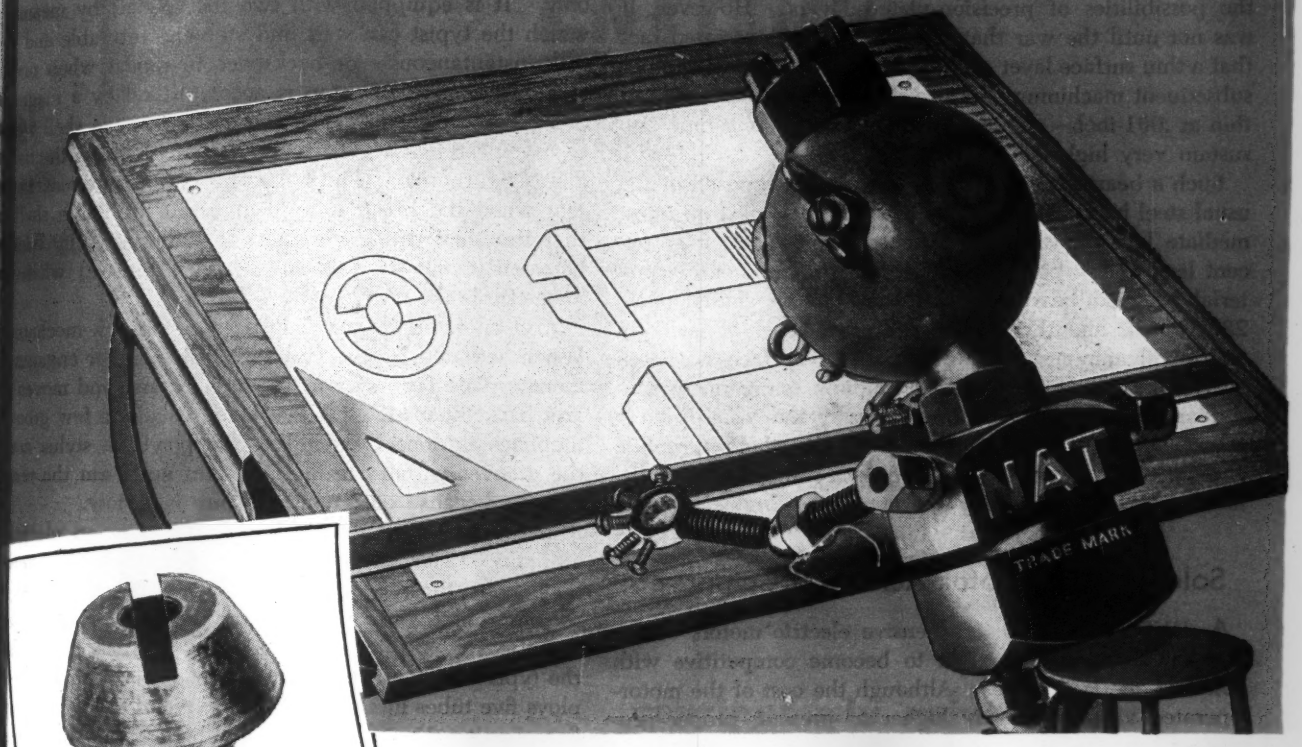
Suitable lubrication capable of withstanding high peratures without freezing at low temperatures cannot obtained. Available lubricants capable of withstan high temperatures freeze at about —30 degrees C Those satisfactory for low temperatures fail in a relati few hours if operation is sustained at about 60 deg Cent. or above. Lubricants do not remain frozen after operation is started and therefore they are ol tionable only because of the added torque required break the bearings loose. Generally it is better to use high temperature lubricants and provide the additi torque required for starting.—*From an A. I. E. E. Sp Program paper by G. O. Schwandt, General Electric C*

Plated Copper-Lead Bearings

TRIMETAL and Micro bearings, composed of a layer of "white" metal bonded direct to a steel b were originally conceived as a result of laboratory t which indicated that if the surface layer were thin enou marked improvement of fatigue properties could be tained. These data have been well sustained in the f and today both constructions are used, the trimetal hav considerable advantage owing to its bearing-like interm diate layer which offers a safety factor that cannot be nored.

Two rather practical difficulties have resulted from trimetal construction: First, in manufacturing bearing this type, considerable expense occurs in maintaining babbitt layer within the thickness range of high perfo ance; and second, in bonding tin-base babbitt on copp lead, difficulty develops unless the copper is "satis with at least 7 per cent of tin. This, of course, makes intermediate layer relatively hard and its ability to ab

THEY NEEDED A BOLT THAT DIDN'T EXIST..



So we designed a Special Bolt..

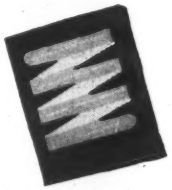
The right fastener for the job!

Here's another typical example of National's Technical Service—a special fastener designed for the particular application when standard fasteners don't meet the need:

In a certain rubber molding operation a bolt was required that could be pulled up tight and used for many applications. Extra large bearing surface was needed, as well as exceptional strength and high "torquing" capacity.

We designed the bolt of alloy steel, with a specially formed slot which permits use of a reinforced driver. This prevents slipping or shearing of the driver point. The large diameter at the base of the head affords ample bearing surface, while the tapered sides reduce the amount of metal in the head, making it possible to upset the bolt, an important cost factor.

You may need just such a service as this to improve your fastenings. Often we can save production time and cost by upsetting a part instead of milling from bar. Let us have your inquiry.



Send for a copy of this case history booklet describing briefly, with diagrams, typical instances of National's Technical Service. Ask for the "Savings" booklet.

National
HEADED AND THREADED
PRODUCTS

THE NATIONAL SCREW & MFG. CO., CLEVELAND 4, O.

foreign material and to adjust itself to the irregularities of the journal, as well as other surface action, is limited.

Recognizing the problems of the trimetal construction and the potential advantages of copper-lead instead of leaded bronze intermediate layers, we were interested in the possibilities of precision-plated layers. However, it was not until the war that it became a demonstrated fact that a thin surface layer can be plated on a bearing without subsequent machining and also that such a layer—even as thin as .001-inch—would last a surprisingly long time and sustain very high loads.

Such a bearing is Clevitte 77, which is composed of the usual steel back with all of its fine qualities; next an intermediate layer consisting of 75 per cent copper, 24½ per cent lead and ¼ per cent tin, which is a true bearing material of good bearing qualities except on shafts below 230 brinell; and then a plated surface layer of lead, tin and small amounts of hardener. This surface has been studied in comparison with lead-indium under many conditions and appears to have no disadvantages.—*From a paper by H. W. Luetkemyer, The Cleveland Graphite Bronze Co., presented at a recent meeting of the Cleveland section of the Society of Automotive Engineers.*

Solenoid and Motor Actuation Compared

ADVENT of small, inexpensive electric motors allows motor-operated valves to become competitive with solenoid-operated valves. Although the cost of the motor-operated valve is slightly higher at present, proper production engineering may give either the cost advantage. Over and above cost consideration, performance requirements may dictate the choice, inasmuch as both have advantageous characteristics for particular applications.

Solenoids have the advantage for conventional selector valves requiring a neutral position. Limit switches are required for motor-operated valves to have a neutral position whereas it is a natural function with solenoid-operated valves. On the other hand, this advantage is lost on valves requiring no neutral position.

Emergency manual override is easier to obtain on the solenoid-operated valves, due to the free movement allowed in a solenoid when not energized. A manual override on a motor valve leads to complications in design. Solenoids have the advantage where fast actuation is required, operating in a fraction of a second, whereas the time of motor-operated valves is usually measured in seconds. This advantage applies, however, to direct-connected conventional poppet design solenoid valves and not to pilot-operated valves which are inclined to be somewhat slow and erratic in operation.

Extremely high starting loads, usually encountered in the larger valves, are handled more effectively by motors which give out high initial torque as against the low initial torque of a solenoid. A motor-operated valve can be readily designed to stay in either extreme position without being energized, whereas a solenoid requires continuous energizing to hold its position, unless locking mechanism is provided. Finally, although solenoid valves are lighter in the smaller sizes than motor-operated valves, the latter have definite weight advantages above ½-inch line size.—*From a paper by J. W. Kelly, chief engineer, Adel Precision Products Corp., presented at the recent ASME aviation war meeting in Los Angeles.*

Precision Performance

(*Concluded from Page* 126)

feed mechanism because it is used for playing back rec only. It is equipped with two foot pedals by mean which the typist can start and stop the turntable and disk instantaneously or backspace to repeat when ne sary. The start and stop is accomplished by a mag brake that engages the light bakelite turntable shell w is driven through a felt friction ring mounted on the h die-cast turntable. The heavy turntable continues t tate when the brake is applied to the turntable she that the shell will be brought to full speed (by fri between it and the felt ring of the turntable) whe magnetic brake is released.

Also operated magnetically is the stepback mecha When actuated by the foot pedal, its clapper engage arcuate plate fastened to the playback arm and move arm back by an adjustable amount, usually a few gro Stepback is done by skidding the playback stylus a the grooves without lifting. It does not harm the re grooves because the stylus pressure is so low.

The transcriber, like the recorder, has an elect amplifier. This permits the use of comfortable liste devices for the typist. One of these is the "soft spea mounted in a desk or floor stand and so arranged the speaker unit is positioned two or three inches f the typist's ear. The amplifier used in this equipment ploys five tubes in a more or less conventional audio-am fier circuit. However, there are high-frequency loss inherent in slow groove-speed recording—and the quency response of the amplifier is corrected to com sate for these. The result is that the overall fidelity of system provides excellent intelligibility.

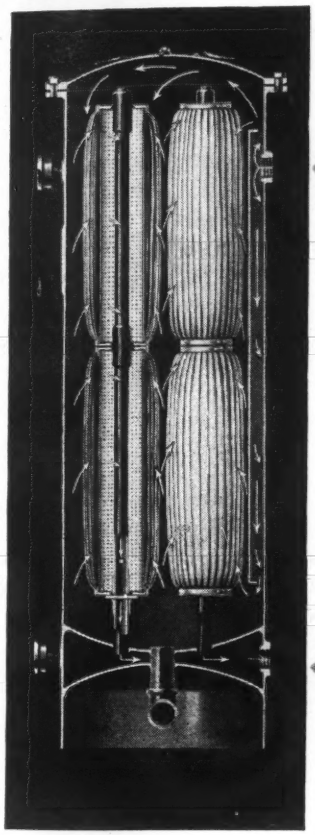
Various types of microphones are available for the cording process. One type is a hand-held microph with a built-in "press-to-talk" switch that starts and s the recording turntable. Another is the desk-mou dynamic microphone which leaves the hands of the o ator free during recording.

In the final analysis, bringing this equipment to the p lic at a low price has primarily been a matter of simpli and practicality in design. As has been pointed out precision performance of the machines could have b achieved by employing special precision parts in des more complex than those adopted. Such equipment, h ever, would have been more expensive than the pre models and, actually, less satisfactory in performance.

Color Code Being Developed

USE OF COLOR to warn, caution and direct is not but at the specific request of the War Department, a Committee of the American Standards association been working on a safety color code for marking phy hazards. The proposed standard is a codification of w ly recognized concepts. For instance, red indicates equipment, danger or stop. Yellow signifies caution for marking physical hazards. Green is for safety; white, black or a combination of the two for housekee and traffic markings.

MAGINE YOUR DIRTY COOLANT ENTERING HERE



Microphotographs: Top shows dirt left on filter paper by unfiltered coolant; Lower shows absence of dirt on filter paper after coolant was filtered through a BRIGGS Z-R FILTER.

AND COMING OUT CLEAN HERE

. . . . continuously rejuvenated, ready for more work and more accurate work . . . ready to give you new coolant performance

Notice the simplicity of the Briggs Z-R Series Filter for Soluble Oils, Light Oils and Kerosene. Nothing complicated, no tricky strainers, nothing to get out of order. IT'S ALL IN THE DESIGN OF THE UNIQUE Z-FOLD REFILL WHICH PROVIDES MAXIMUM FILTRATION SURFACE WITHOUT SACRIFICING FLOW RATE. Combine this unusual design with the fact that the material used in these refills is processed especially for coolant filtration . . . you have the filter that, in some cases, is able to pay for itself the first day it is on the job.

Want more facts? Want to know ALL the advantages of keeping coolants clean? Want to know why a Briggs Z-R Filter does the job better than ordinary multi-purpose filters?

The Briggs Distributor nearest you can give you all the facts. You'll find Briggs Distributors listed in the "Filter" section of most classified telephone directories. Or—write direct.

Briggs

PIONEERS IN MODERN OIL FILTRATION

IGGS CLARIFIER COMPANY • General Offices, Washington 7, D. C.

Postwar Briefs

STAGGERING DEMAND for all kinds of civilian goods both at home and abroad is "the foundation on which America can build a strong transitional economy" as it swings from munitions to peacetime production, says J. A. Krug, WPB chairman, in a report on reconversion. "Reconversion will, in many cases, not even mean the shifting of jobs for many workers. Of the 51,200,000 civilian workers, 44,600,000 are in agriculture, railroading, steel, retail trades, and other jobs that will continue regardless of munition schedules." When a company now making aircraft subassemblies is able to resume manufacture of refrigerators, it probably can use the same plant and personnel even when making new products.

POSTWAR MARKET for 60,000,000 home radio sets is foreseen by Westinghouse. A demand of such proportions will keep the industry at peak production for six years.

PEACETIME TRANSPORTATION is expected to consume about one-third of the total production of aluminum. Aviation will undoubtedly continue to be one of the largest users as the industry switches to cargo transports and family hop-abouts. Predictions for the automobile of tomorrow stress a lighter vehicle as essential to greater economy of operation, indicating that more extensive use of the lighter alloys will be made in the same way they are now being applied in the design of trucks and busses.

POSTWAR AUTOMOTIVE construction will adopt rubber "in torsion" for the springing medium. Already such springs are in volume production and are being used on busses. An outgrowth of application to LVT landing craft, the spring is all-natural rubber firmly bonded to its shaft and shell. Having extensive possibilities for future civilian use, the unit combines well with aluminum to make possible overall lightness and compactness of the suspension system.

COMMERCIAL VERSIONS of the present jet engines will be produced by Westinghouse as soon as military demand permits. These postwar designs, however, will be compact, lightweight gas turbines for driving propellers. The engines will be somewhat similar to those that now produce jet thrust for high-performance military aircraft. Engineering work on these designs is already under way.

INDICATIVE OF POSTWAR thinking and the importance placed on development, distribution and marketing, America's first annual "Products of Tomorrow Exposition" is planned for opening in Chicago next January, subject to military exigencies. Buildings for the show will center on the Chicago Coliseum and will be a complete departure from usual plans. Exhibitors' displays are exp to set the style for many years to come. Consume industrial machines as well as other products will b cluded. The exposition will be an annual event fo introduction of new designs and will make it possibl many industries to design for obsolescence.

IDEAS INCORPORATED in the 45,000 seized en patents will be of value in postwar adaptations such plastics, synthetic finishes, electrical equipment, me alloys, dyestuffs, and processes. In fields such as ce types of plastics, synthetic fibers, alloys, textile machi and lithography we can learn much from Europe. that reason the patents are made available to manuf ers and the government is anxious to "put these en patents to work for the benefit of American economy".

AS A FARMHAND the modified jeep promises to versatile mobile power unit, tractor, light truck or senger conveyance. This civilian Willys jeep has a sp power take-off for auxiliary requirements up to 30 h power. Also, changed gear ratios in the transmis transfer case and axles provide a farm pace of 3 to miles per hour or a road speed up to 60 miles per h either two or four-wheel drive. Wider gears, better l cation and larger bearings are used as well as a large pacity clutch, redesigned steering linkage and impr springs and shock absorbers. Seats are better positi and spring cushioned.

Applying Control Transformers

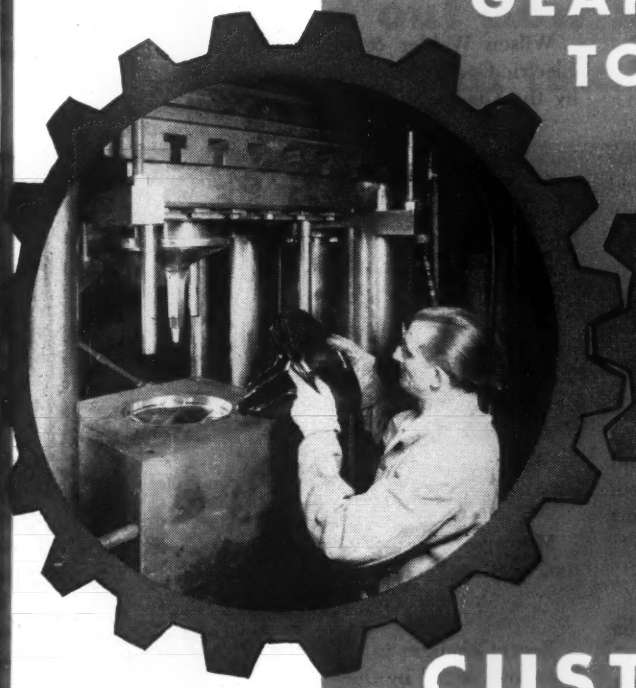
(*Concluded from Page* 136)

trol transformer with no trouble at all. Later the s kind of an application was encountered when a custo wished to use a power-driven wheel dressing devic only a few watts capacity.

As to future developments, undoubtedly there wi improvements in design. It is to be hoped that co transformers will be devised which will allow the co be interchanged just as it is now possible to change in magnetic switches. In other words, the transfo would consist of core and coils only, the core to ha base or feet for panel mounting and so arranged that core can be opened and the coils changed to other r of transformation such as 575/115 or 208/115, etc., also interchangeable to coils with reduced voltage tap the secondary. Thus other voltages besides 115 coul obtained. This would achieve a desirable feature in ing these devices adaptable to special voltage requirem either at 50 or 60 cycles. Control transformers with above features would gain wide acceptance in com cial markets.

Having available more advanced methods of coil w ing with the new high temperature silicone insulating covering and varnishes, control transformers might re become available with practically indestructible wind Such sources of small power would prove to be very and dependable even under adverse conditions of o tion.

GEARED TO CUSTOM MOLDING *Exclusively*



HERE AT CMPC we're committed to just one job . . . and doing that job well. We have no products of our own. We have nothing to offer the dealer or jobber. Instead, all the effort of our seasoned organization . . . all the facilities of our modern 2½ acre plant . . . are devoted to the important task of producing good plastic parts for the manufacturers we serve.

Results have proved the wisdom of this policy. It has enabled us to give undivided attention to the needs of those we serve . . . to make their problems our problems . . . to become, in effect, the customer's plastics molding department. With an organization geared to custom molding exclusively . . . meshing our knowledge with that of our customers . . . giving them the full benefit of our quarter century of experience in plastics . . . assuming undivided responsibility for designing, mold making, molding, and finishing . . . we have built up a nationwide reputation for quality in molded plastics . . . for doing even the tough jobs well.

This is one more reason why you'll find CMPC a good place to come for your molded plastic parts. When you're ready to discuss plans, just ask for a CMPC Development Engineer. There's no obligation.

CHICAGO MOLDED PRODUCTS CORPORATION

Plastic Molders

1028 N. Kolmar Ave. Chicago 51, Illinois

BRANCH OFFICES IN PRINCIPAL INDUSTRIAL CENTERS

BUSINESS AND SALES BRIEFS

APPOINTMENT of Edward Gammie as general sales manager of Victor Mfg. & Gasket Co. has been announced recently. Associated with the company since 1930, Mr. Gammie in recent years has supervised the application of gaskets and oil seals to mechanized warfare. In his new position he will have complete charge of the automotive, industrial and replacement sales divisions of the company.

♦

General Electric Co. has selected a site at Tiffin, O., for a new manufacturing plant in order to meet the anticipated postwar increase in small motors for electrical appliances and in ballasts for fluorescent lamps. Another site is being selected, and both will be operated under the management of the Fort Wayne works.

♦

Reopening of its branch office at Charlotte, N. C., has been made known by The Foxboro Co., Foxboro, Mass. Samuel C. Alexander, 2012 East Seventh St., has been named resident engineer in charge.

♦

At a recent meeting of the directors of The Bunting Brass & Bronze Co. of Toledo, O., Robert R. Hirsch was named vice president in charge of sales. He joined the company in Ju 1944 as sales director.

♦

Wilson Welder & Metals Co. Inc. has appointed G Electric Co. as exclusive electrode distributor in the areas by the Cincinnati, Pittsburgh and Cleveland offices.

♦

Connected with The Ohio Rubber Co. since 1936, Gl Mellinger of the sales department has been promoted t position of assistant sales manager.

♦

Henry A. Mullen has become a member of the sale partment of Ampco Metal Inc., Milwaukee, and will b tached to the Detroit field engineering office as resi welding consultant. Previously he had been associated Ford Motor Co. as welding supervisor at the Willow Plant.

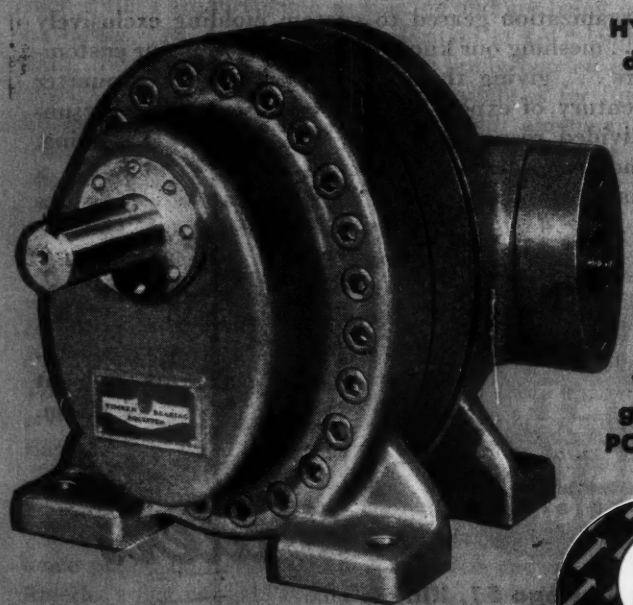
♦

Moving to its new plant at 1520 Twelfth St., S. W., ton, O., has been announced by Mercury Clutch Corp.

♦

Recent changes in the sales and branch house divisions been announced by the Crane Co. Carter T. Pollock, previ manager of the Chicago branch, has been named manag the Central District with headquarters in Chicago. Succe him as manager of the Chicago branch will be W. A. Bu formerly manager of the Cleveland branch. A. N. Rosbo previously manager of the Toledo branch, has succeede

HYDRO-POWER GEAR PUMPS for Oil Hydraulic Circuits



HYDRO-POWER gear pumps are constant delivery pumps designed for generating pressure up to 1000 lbs. per sq. inch. Close tolerances are maintained between working parts. An exclusive gear design reduces the hydraulic load on the gears. Precision tapered roller bearing mounting of gear shafts accurately positions pump gears, with close tolerance between gears and housings. Wear is reduced to a minimum. Adjustments are provided for compensation for bearing wear. Available in capacities from 5 to 60 gallons per minute. Write today for HYDRO-POWER bulletin 440.

hydro power

HYDRO-POWER

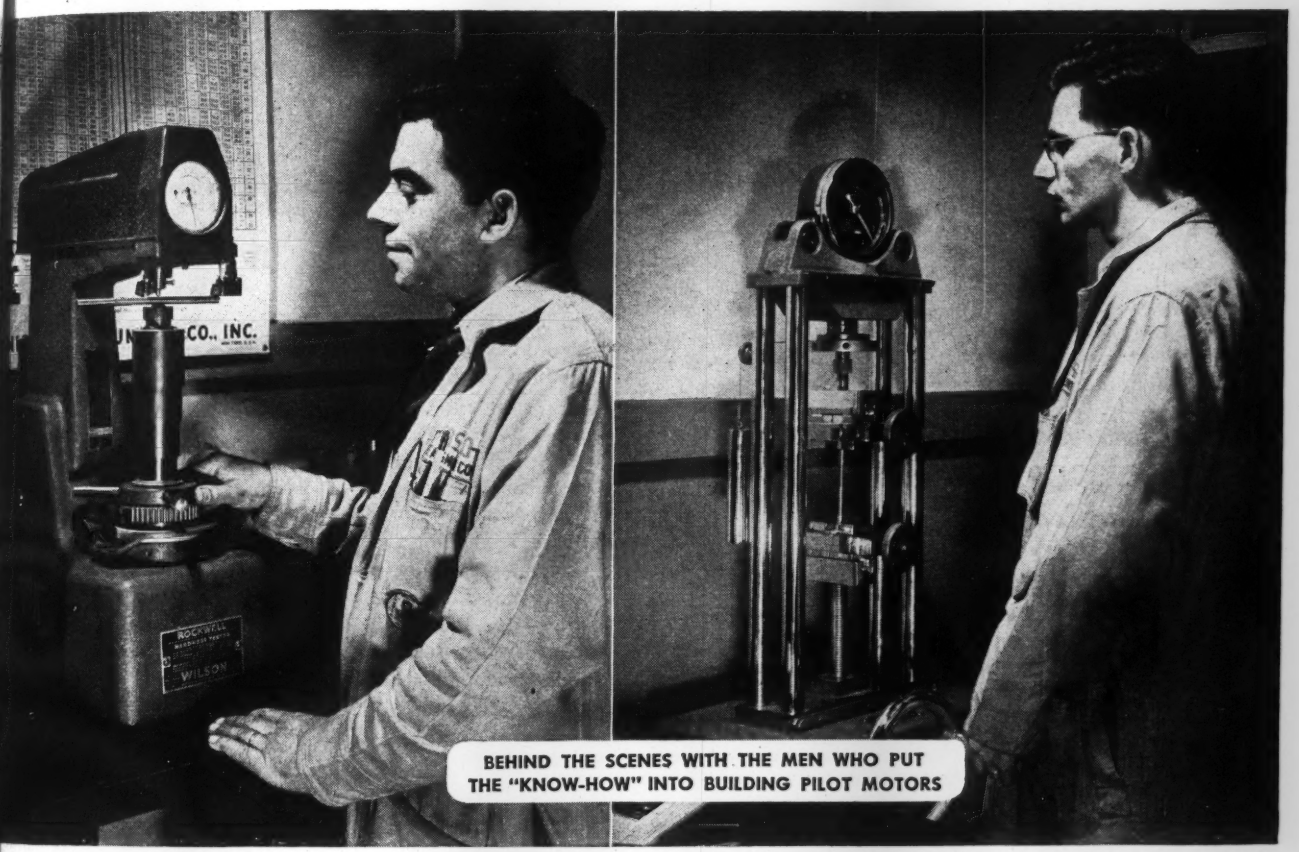
HYDRAULIC PUMPS AND CONTROLS - VALVES - CYLINDER AND RAM ASSEMBLIES - POWER UNITS - SYSTEMS - SPECIAL HYDRAULIC EQUIPMENT

HYDRO-POWER SYSTEMS, INC.

Mount Gilead, Ohio, U. S. A.

We Test a Metal's "Muscles"

Not just to find out how much it can give—but how much it can take!...



BEHIND THE SCENES WITH THE MEN WHO PUT THE "KNOW-HOW" INTO BUILDING PILOT MOTORS

HARDNESS TESTER...*for testing surface hardness of rotor shafts, lamination steel, raw stock for motor cases and other motor parts.*

TENSILE TESTER...*for testing physical properties such as ductility, tensile strength and yield strength of metals used in motor construction.*

The men who staff our Research and Testing Laboratory are, you might say, "from Missouri." They take nothing for granted. For upon the shoulders of these skilled Laboratory Technicians rests the responsibility of okeying or rejecting the raw materials used in the construction of Pilot Shaded-Pole Motors. Trouble-shooting is their business... seeking out flaws in various metals or structural weaknesses which, undiscovered, might affect the efficiency and dependability of these motors in service. And they *do* find out, with the help of the most modern, scientific testing equipment. Thus are the high standards of Pilot quality safeguarded. And thus are the specific requirements of Pilot Motor customers met and maintained.

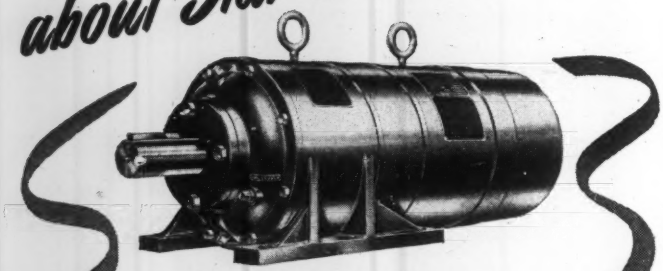
PILOT F.H.P. MOTORS ARE BACK! . . . Available in ratings from 1/500 to 1/15 H.P. Write today for Bulletin M-815 which gives complete information about these dependable, low-cost Motors.

F. A. SMITH MANUFACTURING CO., INC.
401 DAVIS ST. ROCHESTER 2, N. Y.

FASCO

Pilot Shaded-Pole MOTORS & BLOWERS

Nothing Old-Fashioned about Star GEARMOTORS



Star solved a problem for a well known user by designing this Gearmotor with Built-in Brake.

. . . EXCEPT *an extra stamina that's added to its modern design*

Check the reasons why Star Gearmotors are often preferred for punishing services. Users will tell you – "because a Star gives us both heavy-duty construction *and* an unusual combination of design improvements that mean plenty in terms of efficiency and all-'round convenience".

Star Gearmotors will live-up to such praise. Small units are built on a heavy-duty basis. All ratings are made extra-strong throughout. Many users will tell you that a Star's extra-stamina gives them an ample margin of safety to meet unexpected strains . . . often removes the need to use a larger size merely to be "on the safe side".

CHECK THESE FEATURES . . .

1. Center spacing of gears is constant . . . no need to change parts other than gears to change speed ratios.
2. Integrated design avoids a coupling between gear unit and motor . . . promotes compactness and simplicity.
3. Motor pinion is pressed onto motor shaft. No need to replace shaft when replacing worn gear.
4. All motors have anti-friction bearings . . . ball or roller bearings according to the reduction step.
5. Liberal use of materials throughout, and use of an extra tough gear metal, imparts exceptional strength.
6. Motor, gears, everything is made by Star. Complete control of manufacture assures accuracy and uniform quality.
7. Where a mounting problem cannot be solved with standard types, Star's welded steel construction permits a solution at reasonable cost, and prevents delay.
8. Wide flexibility is found in a complete line of gearmotors: ¼HP to 75HP . . . all cycles, phases and frequencies . . . gear reduction range from 2½ to 1 up to 100 to 1 . . . planetary gear, parallel shaft and right angle drive units . . . all types available with Star Built-in Disc Brakes.

If you're particular about gearmotors, we suggest close analysis of Star Gearmotors for your product or plant. For more facts, write – Star Electric Motor Company, 220 Bloomfield Avenue, Bloomfield, N. J.

STAR MOTORS

POWER PACKAGED AS YOU NEED IT

Burbine as manager of the Chicago branch. Succeeding Rosborough, in turn, will be W. D. LaRue, formerly manage the Muncie, Ind., branch. R. C. Danielson, previously man of the plumbing department at the Indianapolis branch, replaced Mr. LaRue as manager of the Muncie branch.

♦

Among other appointments recently made by Cutler-Ham Inc., are those of G. S. Crane, formerly vice president charge of sales and engineering, as president and P. S. Jo as vice president in charge of sales.

♦

Announced by Briggs Clarifier Co., Washington, is the p pointment of W. J. Sommers, 505 Delaware Ave., Buffalo, distributor to cover western New York and northwest Pennsylvania.

♦

Formerly sales manager at Imperial Electric Co., Paul Moore has been appointed motor sales manager of Star Elec Motor Co., Bloomfield, N. J.

♦

With the resignation of Carl W. Hedler as western sa manager and manager of distributors' sales, Norma-Hoffma Bearings Corp. of Stamford, Conn., has made the follow appointments in the home office sales executive person R. L. Miller, sales manager; E. M. Beers Jr., assistant sa manager; G. V. Titsworth, assistant sales manager; C. Brown Jr., assistant to the sales manager; and W. G. Sarge manager of distributors' sales. All of the foregoing will co tinue to report to Frederick W. Mesinger, vice president charge of sales.

♦

Promotion of George R. Hammett from assistant mana of sales to manager of sales of the New Orleans district off has been made by A. M. Lockett & Co. Ltd. In his n position Mr. Hammett has succeeded R. P. Lockett, recen eleeted vice president of the company.

♦

F. L. Jacobs Co. of Detroit, manufacturer of precision au motive parts, has acquired a plant at Holly, Mich. It will operated as a plating and machine unit of a subsidiary co pany, Continental Die Casting Corp.

♦

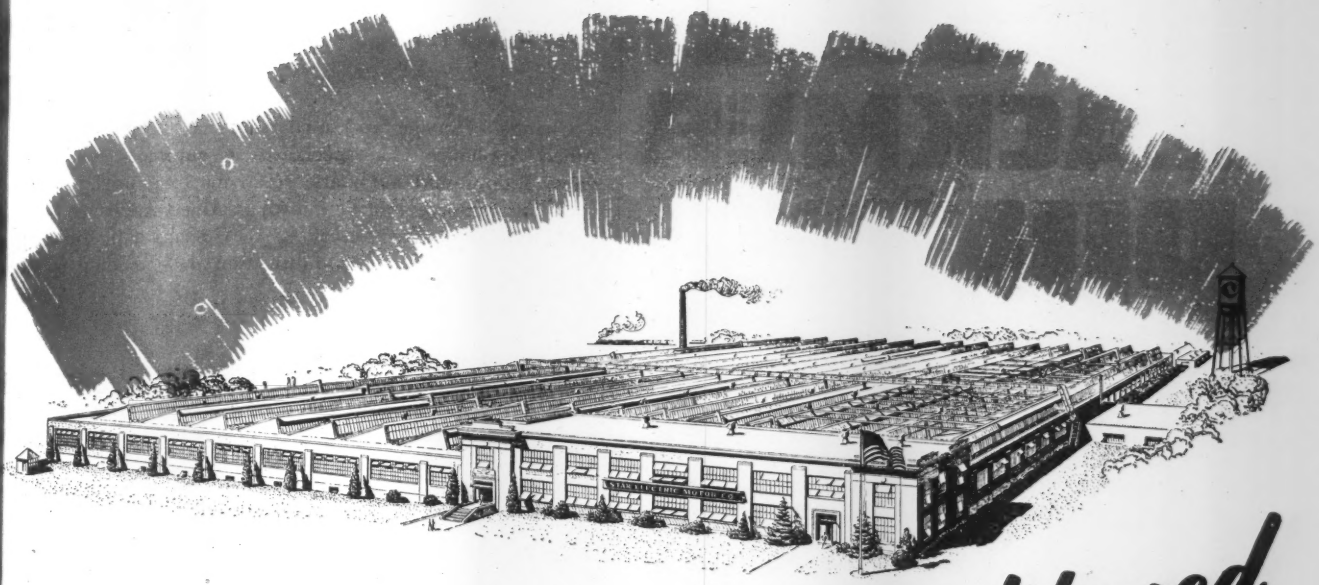
Establishment of a new office at 211 State St., Bridgepo Conn., has been made by Alfred B. King & Co., distributo for The Lincoln Electric Co. of Cleveland. Howard Pennin ton has been placed in charge of the new office.

♦

Made known recently by Bentley, Harris Mfg. Co. of Co shohocken, Pa., is the appointment of Western Fiberglo Supply Ltd., 739 Bryant St., San Francisco 7, to act as the representative on the West Coast.

♦

With headquarters at 18 West Chelten Ave., Philadelphi the Fluid Controls Co. has been made exclusive valve distribu for R-S Products Corp., also of Philadelphia. Territory cover by Fluid Controls Co. will include the Pennsylvania counti east of and including Potter, Clinton, Center, Huntington a Franklin, as well as the New Jersey counties south of and i



So, We'll BE Old-Fashioned

(IN OUR ADVERTISING)

Ad men tell us that plants haven't been shown in ads for 20 years. We're doing it anyway. Because the kind of plant we run has much to do with the kind of motors we make.

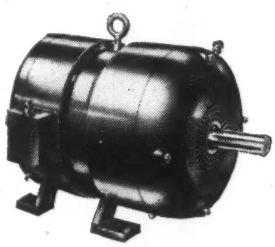
You see above what we call a BIG small plant, (290,000 sq. ft. and 1500 workers). Big enough to build a lot of motors of the kind Star builds. Small enough so we can keep a close eye on all the details that affect quality.

You see a plant that anybody would call modern. And, its equipment is as up-to-the-minute as the buildings, including fine research and testing facilities.

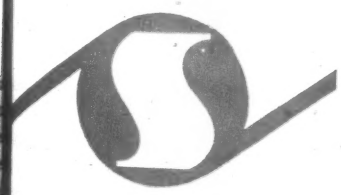
You Don't See the Important Part . . .

No picture can show you the kind of men who build Star Motors, or the way they work. But, come to visit us someday, and you'll see a plant full of real "motor men" . . . men who put the best of themselves, along with the best of materials into the motors they build. See us at our job and we won't need to sell you on making Star your *"Motor Department"*.

With a complete line of standard motors and design know-how that has licked "stumpers" in motor application for many important makers of power-driven products, Star is ready to work with you on any need. Early delivery of some standard motors can be made. For AC or DC motors ⅛ to 200 HP and AC or DC generators to 150 KW, write Star Electric Motor Company, 220 Bloomfield Avenue, Bloomfield, N. J.



AC Fan Cooled Type in Star line of ⅛ to 200 HP motors.



ARMY (E) NAVY

STAR MOTORS

POWER PACKAGED AS YOU NEED IT

BLACKMER PUMPS

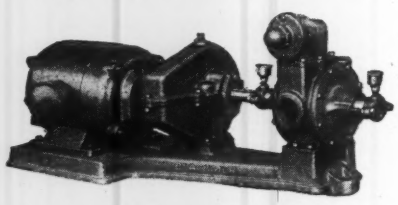
The Key to

- **LOWER PUMPING COSTS**
- **SUSTAINED PUMPING CAPACITY**
- **PUMP DEPENDABILITY**

Write for Bulletin No. 306

FACTS ABOUT ROTARY PUMPS

which explains why the "Bucket Design" (swinging vane principle) maintains pumping capacity by automatically compensating for wear and how the buckets, when finally worn out, are easily replaced and the pump restored to its normal capacity.



WE DESIGN AND BUILD SPECIAL PUMPS
OUR ENGINEERS ARE AT YOUR SERVICE

BLACKMER PUMP COMPANY
1970 Century Avenue Grand Rapids 9, Michigan

POWER PUMPS - HAND PUMPS
· EZY-KLEEN STRAINERS ·

cluding Warren, Hunterdon, Mercer and Monmouth, and entire state of Delaware.

♦

Change of name and ownership has been announced Allied Appliance Co., specialists in automotive and air valve fittings and automatic screw-machine products. Hen forth the company will be known as Allied Appliance & Pl Co. Under the direction of R. B. Gutsch, a plastics div specializing in designing, fabricating and molding of pl parts has been added.

♦

Formerly located at Leominster, Mass., Great Ameri Plastics Co. has moved to 55 North St., Fitchburg, Mass.

♦

Purchase of the precision casting division of B. F. Hirsch I New York, has been announced by Solar Aircraft Co., San Di Calif. Headed by Edmund T. Price, president of Solar Airc the new firm will be known as Solar Precision Castings I B. L. Levinson, formerly vice president and general mana of B. F. Hirsch, will serve in a similar capacity in the n company.

♦

Construction of a new modern daylight plant is under w by Gothard Mfg. Co., Springfield, Ill., which will result i decided enlargement of the engineering and research d partment.

♦

According to a recent announcement by Molybdenum Co of America, Miles K. Smith has joined the Pittsburgh offi of the company in the capacity of sales and service enginee

♦

Under the direction of K. L. Crickman, southwestern ma ager of The Carpenter Steel Co. of Reading, Pa., a new wa house has been opened at 5137 Vine St., St. Bernard, O cinnati. Charles V. Luin and John A. Koch, district repres tatives, will make their headquarters there.

♦

Four new field service engineers have been appointed b Rustless Iron & Steel Corp. to represent its sales division i the Philadelphia, Milwaukee, Chicago and New York ter tories. These are: Walter H. Funk, at Philadelphia; Edwa L. Kelly, at New York; Eric M. Arndt, at Milwaukee, r porting to the Chicago district office; and Edward G. Cresse at Chicago.

♦

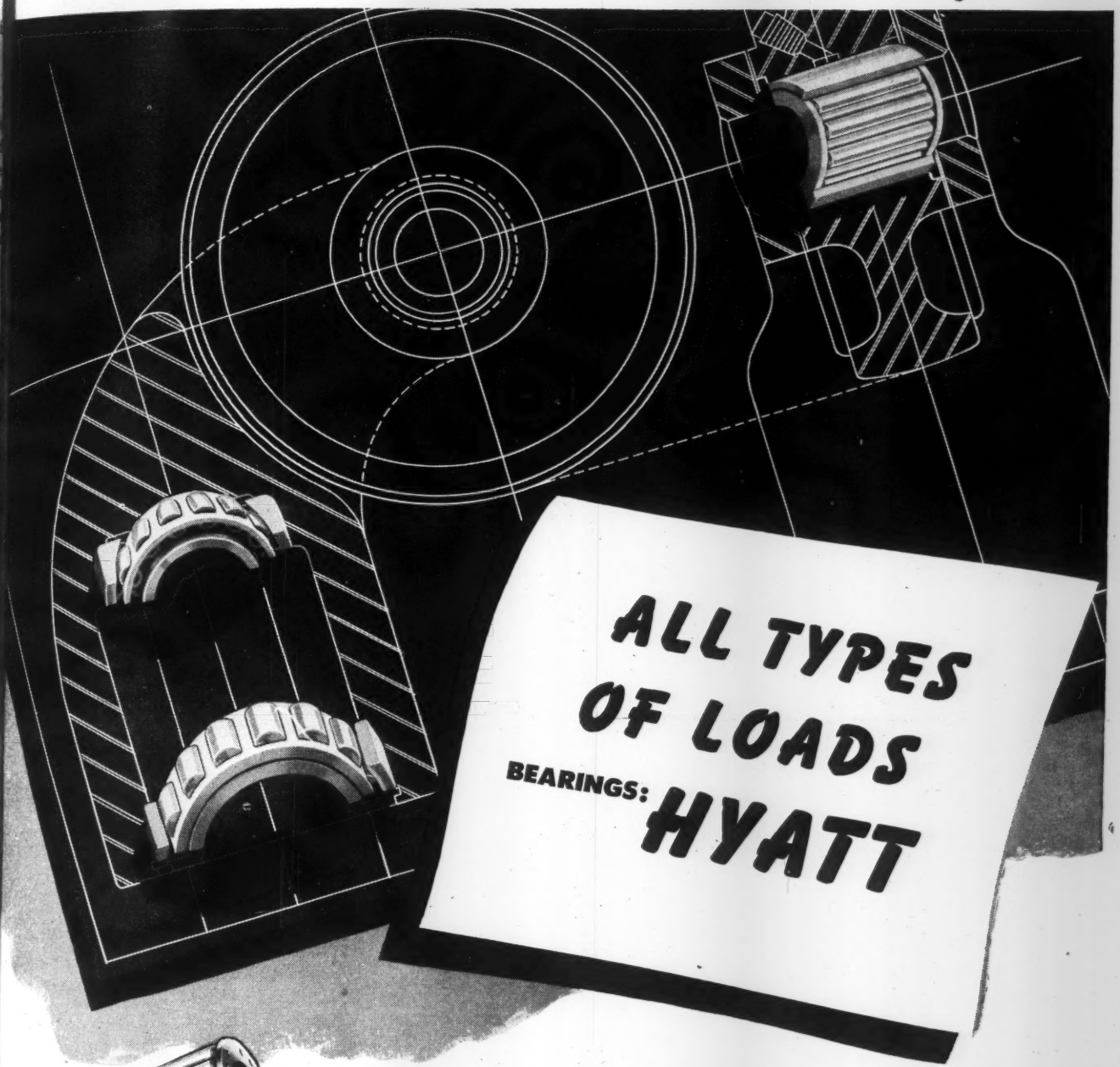
Change of name has been announced by Linear Packi & Rubber Co. Henceforth the company will be known a Linear Inc. No change in personnel or policies has resulted.

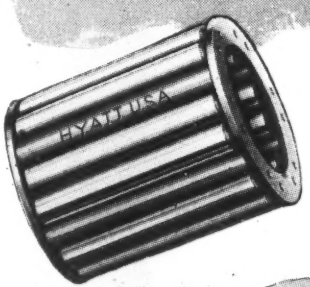
♦

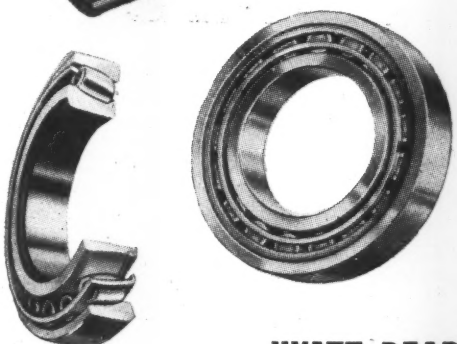
In order to facilitate speedier service to the Northeaster Seaboard area, American Photocopy Equipment Co. of Chica has opened a showroom and office at 19 West Forty-four St., New York.

♦

According to a recent announcement, C. W. Marsellus ha been made sales manager of Elmer E. Mills Corp., Chicag Previously he had been director of sales for Universal Plasti Corp.







Representative of how Hyatt Roller Bearings meet specific application requirements is the plate caster assembly in which there are three types of Hyatts, each doing its allotted job.

Minimizing friction and assuring freedom from wear, is a sturdy Hyatt Junior Series Solid Roller Type Bearing in the wheel hub. Contributing to free turning of the gooseneck and applied at its top, is a Hyatt Spherangular Bearing, self-aligning and suitably designed to carry both radial and thrust loads. At the bottom of the gooseneck is a Hyatt Hy-Load Bearing which provides line contact for better load distribution.

You are invited to call on Hyatt engineers for help with any present or future bearings application problems.

HYATT BEARINGS DIVISION · GENERAL MOTORS CORPORATION

Harrison, New Jersey · Chicago · Detroit · Pittsburgh · Oakland, California